MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The Engineer's Responsibility

Engineering is a young profession, and is still in a state of flux. It is not bound down to tradition nor to precedent, but has the virility of youth; the courage, the energy, the orderly and creative mind essential to the solution not only of its own problems, but of all the great problems of the industrial world. Those problems are both technical and economic, and upon their satisfactory solution the prosperity and peace of the world and the progress of the race depend. The responsibility is great, but we proceed with confidence that the profession will ably meet its obligation.

JOHN LYLE HARRINGTON

(Excerpt from Presidential Address)

JANUARY 1924

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS OF THIS ISSUE

DEPARTMENTAL

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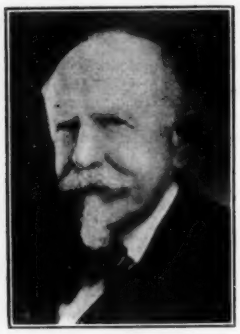
W. W. Galbreath

J. R. Winter



J. R. Freeman

C. M. Allen

E. A. Taylor

Contributors to this Issue

John R. Freeman was born and educated in New England. He was graduated with a B.S. in Civil Engineering from Massachusetts Institute of Technology and subsequently received honorary degrees from Brown University and Tufts College.

Much of Mr. Freeman's life has been devoted to the installation and improvement of water-works systems and the development and conservation of water power. As a consulting engineer and as a member of various commissions and boards he has helped to solve the water-works problems of many cities throughout the United States. In the capacity of consulting engineer he has been connected with such engineering achievements as the Charles River Dam and Boston Harbor improvements, the Keokuk Dam, the Feather River and St. Lawrence power developments, and the Panama Canal.

For many years Mr. Freeman has served as president of Factory Mutual Fire Insurance Companies, and has played an important part in the development of means for preventing and extinguishing fires.

More recently he has been studying China's canal and flood problems, making a thorough study of the rehabilitation of the Grand Canal in Shantung and the control of the Yellow River.

Mr. Freeman is a past-president of both the A.S.M.E. and the A.S.C.E., a member of the Academy of Arts and Sciences, and an honorary member of the Association of Chinese and American Engineers.

* * * * *

Charles M. Allen and **Edwin A. Taylor** describe a new method of water measurement called the salt velocity method. Professor Allen was graduated from Worcester Polytechnic Institute in mechanical engineering in 1894 and has been on the teaching staff at Worcester since that time, for the past fifteen years as professor of hydraulic engineering. During the past twenty-five years he has also had a consulting engineering practice in paper-mill and hydroelectric lines.

Professor Allen has made tests of many power units throughout the eastern United States, using the Alden absorption dynamometer. Among his inventions are a water-wheel flow recorder for permanent installations and the salt velocity method of measuring water. He has made exhaustive researches concerning the friction in gears, and in 1908 built the first circular rating station for current meters.

Mr. Taylor was graduated from Worcester Polytechnic Institute in civil engineering in 1891, and spent the next eighteen years as engineer and superintendent on the design and construction of water supplies and electric railways in New England and other eastern states. In 1909 he moved to the Pacific Coast and for seven years was in Portland, Oregon, as assistant engineer and superintendent of construction for the Water Bureau.

In 1917 Mr. Taylor became chief engineer and superintendent for the Denver Union Water Company, but resigned to enter the Army and remained with the War Department until 1921. Since then he has been associated with Professor Allen on hydraulic research and testing

* * * * *

W. W. Galbreath and **John R. Winter** trace the development of modern stamping practice. Mr. Galbreath, a Marylander by birth, was graduated from St. John's, Annapolis, in 1903, specializing in chemistry. For the next five years he worked in the transportation department of the Baltimore & Ohio Railroad, leaving it to enter as salesman the employ of the General Fireproofing Co., Youngstown, Ohio, manufacturers of steel furniture and other fireproof building specialties. During the next ten years he held successively the positions of purchasing agent, sales manager, and assistant to the president. He resigned in 1917 to accept the presidency of the Youngstown Pressed Steel Co. Mr. Galbreath is a past-president of the Pressed Steel Association.

Mr. Winter started work with the Detroit Electrical Works at the age of sixteen. A little later he began his apprenticeship as machinist and for a number of years was employed in the tool and die industry. His first experience with an automobile-parts manufacturer was with the Kales Stamping Co., Detroit. After that for varying periods of time Mr. Winter was connected with different companies in Detroit, including the old Brush Runabout, Sampson Truck, U. S. Motors, Kelsey Wheel, and the Geier Pressed Steel Co. He is now general superintendent of the Youngstown Pressed Steel Co.

* * * * *

John Lyle Harrington, whose Presidential Address at the recent A.S.M.E. Annual Meeting so well defined the public obligations of the engineer, for many years has been in close contact with engineers in many branches of the profession. He is a member of the A.S.C.E., A.S.M.E., Engineering Institute of Canada, Institution of Civil Engineers, American Railway Engineering Association, and the American Society for Testing Materials.

Mr. Harrington was graduated from the University of Kansas with the degrees of A.B., B.S., and C.E. Later he received his M.S. from McGill University. In his professional life he has engaged in the design and supervision of the construction of large bridges, as a consulting engineer and with various bridge works He developed the vertical-lift bridge and a variation of it, the movable deck.

* * * * *

The Report on the Present Status and Future Problems of the Art of Cutting and Forming Metals has been prepared by the Special Committee appointed by the A.S.M.E. Research Committee to foster research in the field of metal working. It is intended as a general discussion of the subject preliminary to the study of various problems connected with the cutting and forming of metals.

The Forty-Fourth A.S.M.E. Annual Meeting

Over 1800 members and guests attended the A.S.M.E. Annual Meeting held in New York, December 3 to 6, 1923, participating in the technical and social events. A running account of the technical sessions will be found on pages 35 to 39 of this issue. An account of the social affairs appeared in the December 22 issue of the *A.S.M.E. News*.

MECHANICAL ENGINEERING

Volume 46 January, 1924 No. 1

The Fundamental Problems of Hydroelectric Development

By JOHN R. FREEMAN,[1] PROVIDENCE, R. I.

WE ARE now in the midst of the greatest activity ever known in hydroelectric development and problems of unprecedented magnitude are before us.[2]

Coöperation between our great national engineering societies in discussing these great national problems, in which the work of the civil, the mechanical, and the electrical engineer are closely interwoven, is both pleasant and profitable. In the hydroelectric field the several engineering specialists must all work together from start to finish. One cannot begin where the other leaves off.

Today the most fundamental problems of hydroelectric development, interconnected power, and superpower are those of public relations and future public welfare.

This kind of a meeting may serve a useful purpose far beyond that of interchange of information between specialists in power development, if it can interest engineers working outside of this special field in the broad aspects of some of these fundamental problems.

Conferences on this topic will have their greatest usefulness if they can be made to arouse a campaign of education among the voters and their representatives in legislative halls, toward removing the present lack of understanding and make plain the true relation to public welfare of widespread transmission of hydroelectric power.[3]

Scope of Discussion

The committee on this joint meeting has asked me to open this evening's discussion.

The A.S.M.E. Secretary tells me that society publications have been overfed with papers on station detail and that it is desired we now confine our talk to fundamentals.

I am asked to round up and set forth, so far as I can, briefly, some of the chief underlying principles. Others who follow will amplify my remarks so far as the brief time allotted to each speaker will permit.

None of us in this time and place can treat his subject exhaustively or minutely. The literature upon the details of power development would go far toward filling the famous five-foot bookshelf, and there is much of interest in recent developments that remains to be written up.

Agreement is not to be expected among all of us, coming, as we do, from different fields, with different points of view; nor can we settle the great problems here. Our chief purpose must be to promote and direct discussions along useful lines among engineers, business men, and those in public life.

The very fundamentals can be quickly stated:

1 A hydroelectric prospect must show a profit on the investment.

2 It should be so developed as to contribute to public welfare in the highest degree.

These principles seem so self-evident as to require no extended discussion, but to prove up, on their application to a particular prospect, may require an enormous amount of work.

Change and Progress within Speaker's Memory

Possibly the committee selected me to open this discussion in the expectation that I would say something in a sketchy way of the fundamental changes in these problems that have come about within my memory, and compare past conditions and the methods of solving their problems with present conditions, as a preliminary to suggesting the directions in which to look out toward future progress from present achievement.

It is a little more than 50 years since I began work in the engineering office of the water-power company at Lawrence, Mass. At that time Lowell, Lawrence, Manchester, and Holyoke had come into their prime, and often were visited by engineers from other parts of the United States and from foreign lands; and often, as a youngster whose time was not particularly valuable to his employer, it was my good fortune to show these visitors around.

Fifty years ago, there were no better water-power developments than these, in America, or in the world. Here at Lowell and Lawrence the great problems of turbine versus overshot or high-breast water wheel had been worked out by Boyden, Francis, and Swain, and here turbine efficiencies had been achieved which stood unchallenged for nearly half a century. And in the testing flume (or hydraulic laboratory) at Holyoke the way had been shown toward obtaining larger power in smaller compass than had before been even dreamed of. Also at Lowell and Lawrence, in these early days, under Storrow, Francis, and Mills, the art of measuring large quantities of flow of water accurately had been worked out better than elsewhere. Storrow was the best-educated engineer of his day in America. Boyden, Francis, Swain, and Mills were men of genius.

Costs: Hydro vs. Steam

The fundamental question about water power that I heard most debated 40 to 50 years ago was its relative cost compared with steam power. That question is still with us. Every customer of the power company had ideas on this topic; but we had object lessons that water was cheaper in the price that the water-power company actually obtained from those factories which had emergency steam engines standing idle.

Rates for water at Lawrence had been shrewdly put at nearly as much as the traffic would bear, about $20 per hp. per year for the mere right to draw water for power from the canals nominally 16 hours per working day but actually about 10 hours. At Holyoke the price had been much smaller, but all primary power had been sold out long ago, mostly to paper mills for 24-hour use.

The earlier American factories nearly all sought water-power sites, but the perfection of the steam engine with automatic cut-off already had brought it into close competition with the water wheel.

Address at the Session on Hydraulic Power, Annual Meeting of The American Society of Mechanical Engineers, New York, December 3 to 6, 1923.

[1] Past-President A.S.C.E., and A.S.M.E.

[2] We are told applications have been filed with the Federal Power Commission alone (which is far from covering all water-power prospects) for projects involving the installation of more than 21 million horsepower and that they have issued permits and licenses for an aggregate of 7 million horsepower. Meanwhile the sum total of water horsepower already developed in the U. S. is only 9 millions. (Figures on authority of O. C. Merrill in the address mentioned in following footnote.)

Perhaps, like most water-right filings in the West, these power-right filings are too optimistic in their estimates; nevertheless these figures tell a story of a wonderful awakening.

[3] This matter of creating a better understanding by the public in hydroelectric development and of the influence of hydroelectric development on the welfare of the state was admirably set forth a few months ago in address by Mr. O. C. Merrill, secretary of the Federal Power Commission, before the Empire State Gas and Electric Association, reprinted in the *Electrical World* of Oct. 20, 1923; which issue also contains a tabular view of the location in different parts of the U. S. of generating capacity (steam and water power), aggregating 17,715,484 kva., figures that the mind can hardly grasp.

Power cost is but one of many factors determining location, and more steam-driven cotton mills were being built 40 and 50 years ago than those driven by water power. It was found that prompt and cheap transportation for raw stock and finished product, or the easy labor market of great cities, were often stronger attractions than a small saving in power cost for textile mills and machine works, where power was a small proportion of total cost of manufacture. Moreover, steam power often could be made cheaper than water power for woolen mills, dye houses, etc., by conserving the heat of the engine exhaust.

Most of the southern New England water-power sites that could be developed economically had been already occupied, and many water powers on streams of small and irregular flow had been developed that would not today be worth while; although once built and the cost absorbed, it still pays to run them. Where water power had fixed the location, often growth in power demand had to be met by steam, regardless of cost, and a common condition found at the larger country mills was that of employing more steam power than water power. Lowell, 40 years ago, had come to have twice as much steam power as water power (as I remember the figures).

Fifty years have brought a wonderful increase in the amount of power used and in methods of developing it, but costs per horsepower in the broad view show small change. The cost of coal has doubled, but higher steam pressures, larger power units, the steam turbine, and the economies of the central station have cut coal consumption per horsepower-hour in half.[1]

In water-power development the unit costs per pound for machinery and per cubic yard for structural material have doubled. Although the efficiency of the hydro unit has increased at best only from 83 per cent to 93 per cent (and for some time has been close to the end of the road), the costs of installation, maintenance, and supervision have been held down by a wonderful concentration of power into single units, under terrific head, and by a revolution in the features of design for large developments, so that with all these changes there has been remarkably small change in 50 years in cost of either hydro or steam power in large quantity, reckoned at the prime mover.

And in all these new schemes of superpower—St. Lawrence power or steam stations at the mouth of the mine—I see no chance for any substantial reduction in power cost at wholesale below that which we now enjoy in either the near or the distant future.

Future Holds Small Hope of Cheaper Power

In a broad review and for a round figure we may regard the general station cost today, hydro or steam, as 1 cent per kw-hr.

One cent per kilowatt-hour is equivalent to $22.36 per horsepower year for 10-hour power drawn on 300 working days. Although I have no recent or broadly collected figures, and freight rates on fuel cause wide differences in cost, it appears probable that few textile factories in New England with the best large reciprocating engines are now obtaining their power for less than, say, $30 per hp-year, which would be about equivalent to 1.5 cents per kw-hr. for 9 working hours where all costs are reckoned in. I am told that the best large stations today can cut this figure in half, for cost at bus bar. It is estimated that with units of 30,000 kva.—steam at 600 lb., coal at about $5—the cost at bus bar can be brought to 6 mills per kw-hr. under a favorable load factor, and there are a few great hydro stations at localities that are few and far between where it is reported power can be put on the bus bar at 3 mills per kw-hr., including all proper charges.

But on top of the station cost there must be reckoned a substantial cost of distribution, and there are large stand-by charges in the yearly load factor of a 9-hour day.

Let us not be too optimistic about cheaper power coming from St. Lawrence, or from coal mines, over the superpower line to central New England or Greater New York. I, for one, strongly incline to the belief that factories in Lawrence will be glad to get water rights at the old figure of $20 per hp. 50 years hence, and that 1 cent per kw-hr. (perhaps 1.25 cents) at wholesale in big blocks will be the lowest price or cost attainable by the great factories at Lowell and other Mid-New England industrial centers 50 years hence and in all the years between. The great benefits of the superpower system and of the distant sources will come in lessening the investment of capital by the industrial pioneer, and in many other ways than by reducing present costs per horsepower-hour.

The Start of a New Era

In general, 30 to 40 years ago water-power developments were moving slowly, waiting for the great impetus soon to be given, first by the enormous increase in the demand for cheap paper from wood pulp, and next by long-distance electrical transmission, followed, 10 years later, by demands of the electrochemical industries, particularly that of making aluminum from purified bauxite.

The U. S. Census for 1880, under the broad vision of its director, Gen. Francis A. Walker, later president of Massachusetts Institute of Technology, published two big, thick volumes on water-power development, based largely upon field inspections by George F. Swain, Dwight Porter, Herman Hollerith, and others among our members since become famous, which was a thoroughly admirable review of the state of the art and extent of development in the U. S. 43 years ago, and was so instructive a piece of history that we may well urge that the next census prepare a similar volume which will set forth, with authority, the wonderful story of a half-century's advance in the manufacture of power, both water and steam.

Thirty years ago the greatest modern power consumers—electric railways and municipal lighting systems—had scarcely been brought into existence by the use of alternating current and long-distance transmission, and the great water-power sites in northern Maine, northern New Hampshire, New York, and Vermont had not been called largely into use by the modern demand for newspaper pulp. Thirty years ago the water-power company at Lawrence still had water rights for factories unsold, while customers were slow in coming. Along each of the chief New England rivers were undeveloped power sites, at least one of which still runs to waste.

I saw something of the pioneering work in high-speed engines, for I knew intimately John C. Hoadley, deep student, prophet of the great future of power, and most lovable of men, and was well acquainted with his shop and his assistants, Pardon Armington and Gardiner Sims, when they were building high-speed engines for the early small Edison generators. Sims showed me one of these running at about 1000 r.p.m. as the very end of things in speed. They put Hero's steam turbine on the title page of their catalog as typifying speed in steam power; far from imagining that its modern development in the great central-station turbine would spoil the business of building reciprocating steam engines and shut up most of the large engine works. I was a bystander at several of the early, tentative installations of the dynamos of Brush for arc lighting, and of Edison for incandescent lighting, as these were tried out in a hesitating way for lighting a few places in factories and streets.

How pitifully small those first plants now seem! And how wonderful were the developments of the next 25 years! The great Corliss steam engine, at whose gigantic frame we marveled at the Philadelphia Centennial—the dominating central feature of the great machinery hall—was only of about 1300 hp![1]

The ponderous steam engines used in emergencies, such as backwater or drought, at the Pacific Mills, the Atlantic Mills, and the old Washington Mills, at whose majestic proportions and giant power we youngsters marveled, were each of less horsepower than the Liberty motor, model of 1918, in an airplane, weighing 825 lb. and giving 450 hp.

Few of the largest water turbines in Lowell or Lawrence were of more than 200 hp. each. An 80-in. Swain wheel of about 800 hp. put in at Lawrence about 45 years ago was regarded as a monster, as "the most powerful turbine ever built," and finally its buckets (of cast-in plates) broke loose, unable to stand the strain of 30 ft. head.

[1] This refers to average practice of the times—not to the few best plants. An admirable review of the state of the art of steam-engine practice was prepared by John C. Hoadley in 1884 for the meeting of the British Association for the Advancement of Science in Montreal, and printed for private circulation under the title of Steam Engine Practice in the United States, which gives several examples of engine economy close to present-day standards of best reciprocating engines. The great change is to the steam turbine in the central station, with single units 50 or 100 times as powerful as the common factory engine of 40 years ago.

[1] Steam pressure at throttle, 100 lb.; cylinders 40 in. diameter, 10 ft. stroke; 36 r.p.m.; cut-off at 25 per cent of stroke.

The one turbine which I saw started at Pit River, California, last October, under about 450 ft. head, had more power (40,000 hp.) than all 65 of the Lawrence turbines combined, plus all of the Lowell turbines. And a single one of the recent turbines at the Queenston-Chippawa plant developed 60,000 hp., or more than the total obtained in all three of the old water-power cities—Lawrence, Lowell and Manchester—from the Merrimac River, which we used to say was "the hardest-worked river in the world."

Things were moving slowly in water-power development and we felt we were near the summit of things, until two new factors came over the horizon: wood pulp and electrical transmission.

Steam felt the new stimulus 10 years before hydro woke up, but since that time a merry race has been on between the two, both in size of unit and in economy of service; first one winning and then the other, as circumstances favored, and the end is not yet.

The changes of 30 years are far less in the cost of power than in the scale on which it is developed, its widespread distribution, and its ever-increasing uses.

Power, Founder of a New Epoch

Twenty-eight years ago I heard George S. Morison, President of the Am. Soc. C. E., deliver his presidential address on the New Epoch in Civilization Opened by the Manufacture of Power. His statement was so strong and clear that its keynote has been ringing in my memory through all these years. Later this was combined with a Phi Beta Kappa address at Harvard and an address at Rennsalaer Commencement, on other aspects of the same topic, and published in a little volume under the title, The New Epoch. Edward Everett Hale told me that Morison's was the most inspiring Phi Beta Kappa address to which he had ever listened.

President Morison developed his thesis that just as the several steps in the advance of human kind, from animal instinct, through savagery and barbarism, to civilization, had resulted successively from the use of fire, from the invention of the bow and arrow, the invention of pottery, the domestication of animals, and the manufacture of iron or bronze, until the epoch of civilization began with the invention of a written language, which stored up the observations and experience of one for the benefit of all who followed; so now a new and far-reaching epoch in civilization had begun with the manufacture of power, increasing the power of the hand of man almost without limit, and making neighbors of all the world. And he argued that this new epoch had hardly begun, although the power expended by one of the great steamships of 25 years ago in a single voyage across the Atlantic, was greater than that required to take from the Nile and place into final position every stone in the Great Pyramid!

Since Morison's time the advance has gone on with a stride that has far outstripped even his vision.

Kind and appreciative words should be spoken of the financiers of vision who have risked much and sometimes lost heavily in pioneering on these great machines by which the general welfare has been so greatly advanced. A high officer of one of the big concerns told me how more than $200,000 had been spent without success in developing a new steam turbine, and the whole seemed about to be sorrowfully charged off and the scheme abandoned, when after a long debate, just one more allotment of $10,000 was granted with the firm agreement all around the board that this should be the last—and this last-chance grant brought success.

The great hydraulic turbine has become one of the most marvelous machines ever fabricated by the hand of man, marvelous in the efficiency with which it can extract 94 per cent of the energy of a great falling current of water in the short space of 3 or 5 ft. of travel through its runner within less than one-tenth of a second of time! And it can do this 24 hours per day, 7 days in the week, year after year, with marvelously small cost for care and oversight. The wonder of all this came over me a few months ago in a hydro-electric plant of 30,000 kva. with *only two men* present to care for it all! Picture two men guiding and grooming not that famous 20-mule team, but one of 40,000!

Next day I got the superintendent at another plant near by to hoist the spillway gate so as to let a quantity about equal to the discharge of one turbine fall nearly a hundred feet; and watched its tremendous display of force in high foaming surges and tumbling eddies, in comparison with the quiet discharge of equal volume from which the nearby turbine had extracted the energy. Such a display of force appealing to the eye speaks louder than words, of this triumph of engineering in controlling one of the great forces of nature for the benefit and convenience of man.

Change of Method in Solving Problems of Development

I recall with much interest that about 40 years ago, Sir Paget Higgs, of England, knighted for services in laying the first successful Atlantic cable and an interested student and prophet of electrical development who had become fascinated by the idea that when a direct electric current was led into an electrical generator it would run this backward and convert it into a motor, came to Lawrence to study its water power and the uses thereof in the factories, chiefly to find out if there was important practical use for electrical transmission of power; and I had the good fortune to act as his guide along the power canal and through the Pacific Mills. In the evening I heard him hold forth at the chief literary club of the city to local captains of industry and business men. He was regarded as "interesting, but too visionary." The verdict was that there was nothing practical in his great idea!

The most fundamental changes in scheme for developing a great water power that have come in the past 30 years have come from the distribution of power by electricity. Then *water was distributed* to the turbines, now the *power is distributed* to the machines in the factory.

The scheme followed at Lowell, Lawrence, Manchester, Holyoke, and at most of our large old-time factories, of building a dam near the head of the rapids and distributing water by long canals, has been put badly out of date by electrical distribution.[1] Now canals are abandoned, the power house is built into the dam, notwithstanding the cost of the dam may have to be vastly increased by building it or greater height down near the foot of the rapids in order to use the whole fall; or if the dam is not placed at the foot of the fall, a deep, long tailrace is excavated instead of a canal.

Some of the most revolutionary changes are:

a Dispensing with a long power canal controlled by head gates by building the power house into one end of the dam and thereby lessening ice troubles and making efficient any surplus of flood head, instead of losing it by throttling in sluiceways and canal head gates.

b Higher heads on turbine—even to 825 ft. as against the common old 30- or 40-ft. limitations—are made practicable by stronger design.

c Dams are built to the extreme limit of height permitted by river bank and flowage rights, by means of larger tools and with greater confidence about the theory of design, so as to form the largest practicable storage reservoir and give both better storage for peak loads and flow, for Sunday storage, and for a drought reserve.

Whereas, in the old days 30 ft. was about the ordinary limit in height for dam and 10 ft. the prudent limit for crest depth in floods, one now does not hesitate at water-power dams more than 100 ft. in height, and fears not whatever crest depth the flood may bring.

d The siphon spillway has become well established as a safe and efficient means for conserving the power of heads up to nearly the full limit of flowage height and meanwhile adding largely to the volume of storage available for regulation.

e Turbines are made far larger than formerly, are given the highest practicable speed consistent with maximum efficiency, and the number of units at one site is made the fewest possible.

f The old-time ponderous bevel gears on top of the turbine, with their frequent breakage of teeth, are unknown in modern design; and the shift from vertical to horizontal axis of turbine for a more efficient attachment of main driving belts or generator, now is far in the background. Inside the factory great toothed gears, heavy lineshafts, and great belts for distributing power from water wheel or engine have mostly become things of the past.

g Nearly all friction loss of transmission from turbine to generator is avoided by placing the generator on the top end of a vertical turbine shaft, and notwithstanding enormous increase in weight of runner and rotor up to four hundred and eighty tons for example,

[1] How a new departure in the power layout of Manchester, N. H., was made two years ago, has been told in a professional paper by Arthur T. Safford, Mem. Am. Soc. C. E., published in Proceedings of the Boston Society of Civil Engineers.

the troubles of the old-time foot step bearing have been done away with by top suspension, or by a bearing in which viscosity drags the lubricant under the load. Four hundred and eighty tons spinning around apparently lightly as a schoolboy's top, "asleep," surely is a marvellous triumph of engineering!

h Turbines are made taller and so designed as to obtain highest efficiency when at less than full gate opening, thereby providing a surplus of power, or overload capacity, for emergencies and speed regulation.

i The high-speed runner, trimmed down almost to the proportions of a ship's propeller, is establishing a firm place for itself in the economics of design for special conditions.

j The utmost care is taken in design to prepare smooth passages and easy curves for the water passing through, and a spiral approach for further lessening eddy loss is now universal. (It is worthy of note that Uriah Boyden, the hydraulic genius of 70 years ago, used spiral approach and top suspension in his best designs and made his price contain a bonus for each added per cent of efficiency obtained.)

k The so-called Leffel type of speed gate, regarded in the old days as too "trappy," too loose, and too leaky, has in these later years become glorified by accurate machinery into the standard type for all makers and up to the very largest sizes.

l The ideal of the automatic hydroelectric station for small powers is here in such perfection that after filling the oil cups on the bearings one can depart, lock the door, leave it in solitude for a day, perhaps for a week; starting, stopping, and regulating, all under control of the man who throws a switch or presses a button, miles away.

m The electric steam boiler has become an economic possibility for absorbing surplus power until profitable customers can be found. With steam coal at $10 per ton, the equation stands giving a value at about $13 per hp. per year for continuous 24-hour, 7-day power, (the precise figure varying a little according to the respective efficiencies of the coal-heated boiler and the electrically heated boilers compared). Correspondingly with $5 coal, the equivalent power price would have to be about $6.50 per 24-hr. hp. per year, or *less than the mere interest*, exclusive of maintenance, on an irreducible minimum cost of development. For heat processes, as, for example, wood-pulp digesters, the 24-hour demand is common and for such year-round, day-and-night work the electric boiler may be a great help in meeting interest charges during the early years. The hydro power could hardly enter the competition and earn dividends on a 27 per cent annual load factor, which corresponds to 8 hours' use daily for 300 working days per year, unless coal was costing more than $40 per ton.

n The foregoing changes relate to the power-house design. Other changes of even greater importance to the builder of a new factory have been brought about by the distribution of power by electricity throughout all parts of the factory and throughout city and county. Now the central station and the public-service corporation relieve the founder of a new industry from raising the large sum necessary for developing a water power or for buying boilers and engines. His capital is thereby conserved for building a larger factory, or if the new enterprise is something of a venture, he can try it out with a smaller investment. Moreover the economies of large power units, of wholesale scale of operation, and the diversity factor in a widespread system permit him to buy his power cheaper than he could make it; and more than one large factory with a good steam power plant already installed has found economy in shutting it down and buying from the public-service circuits. (If he has a turbine he keeps it running merely to save fuel.)

o One of the most fundamental changes of all is that of the view of the public toward water-power development. Formerly its only interest was in welcoming the development of power because of the benefits from employment that followed in its train, and with little or no thought of public control. Now where any general public service is to be given there is oversight by public officials at almost every step in development, and it is entirely possible that an unwise control may work harm to the long-range public welfare.

This change has come through the development of widespread public-service power systems and their demands upon the natural resources of river flow, from the necessity of invoking of the state's right of eminent domain in order to create a great development, or sometimes by reason of title still retained by the public in the river bed and reservoir sites essential to power development.

A great awakening has been going on regarding the need of some public control, lest rights given up by the public, or possible to obtain only through legislative act, be capitalized at all the traffic will bear.

The principle has already been established in some states that "Values inherent in a public resource developed and used in essential public service by an agency created by law for that purpose shall not be capitalized in excess of amounts actually expended in acquisition," and this seems right and for the best.

Good practicable methods for safeguarding the public from unreasonable rates and invested capital from cutthroat competition or political confiscation are being worked out through public-service commissions, which promise much better service and much lower costs than possible through public ownership and a management under political control.

There is not here time in which to go into detail about the reasons that have led to these changes, nor about the various dangers that lurk in unwise control.

Interconnection of Power Systems

In hydroelectric practice the facility of long-distance transportation of power is the outstanding achievement of the past 20 years, and one of the most interesting features is the way steam power and water-power installations at widely separated places, each pumping current into opposite ends of the same line, have come to supplement each other, economizing both power and transmission, uniting and interchanging the variable power developed in the mountains or foothills from water which is plenty in springtime but scanty in midsummer, with steam power developed at the seacoast from seaborne coal or oil. The electric current flows with equal facility in either direction.

It will surprise many to learn, for example, that more power is sent forth from the Narragansett steam station in Providence from its 60,000-hp. steam turbine, back into the country over the widespread lines of the New England Power Company, than is brought to the industrial centers near the coast from the northern Connecticut River and its tributaries. Hydroelectric companies on variable streams less favored with reservoir sites are becoming connected up with steam reserves at the seaboard, and all are rapidly becoming interconnected.

Few persons not directly engaged in power transmission realize the extent to which this interconnection has been quietly going on. In Providence not long ago, within about ten minutes after a burn-out near the central station, power was flowing in from four neighboring cities, so that all went well. At Chattanooga last year I saw the great hydroelectric station completely shut down, and the whole flow of the Tennessee River held back half a Sunday for purposes of inspection, and meanwhile current was flowing in, sufficient for all demands, from the works of three or four other public-service corporations many miles away.

Just now there is some confusion of thought in the present popular interest in superpower schemes between "superpower" from great new stations and the *interconnection* of central stations, by which one station can help another and by which the steam station—far more flexible than the hydro in taking overload—can help out the hydro station in low-water seasons, while the hydro, in its flush times, can save coal to the steam station.

Each Site Has Its Own Problems

Broad generalizations about water-power problems have more special exceptions than followings. Each prospective site for hydroelectric development has problems peculiar to itself, and on beginning an investigation the chief problem at any one site should be roughed out from the two different standpoints of

1 Profit to investors
2 Public welfare.

From each standpoint both a close-up view and a long-range view into the future are necessary; remembering that the present value of a power site rests solely on possibilities of its profitable use. There are many enticing prospects of water falls on flashy streams, which investigation will show to have only the value that pertains to beautiful scenery, for perhaps 50 or 100 years to come.

A site is of no more value for hydroelectric power than for a cow pasture except as its potentialities can be made to minister to industry or public welfare. And although its prospects may figure into many millions of horsepower-hours, one must first find the $100 or $200 per hp. to fit it to produce power, and before this one must know definitely what work there is that really needs this horsepower, what price it can pay per horsepower-hour or per kilowatt-hour, just how much of the power is "firm" or primary power, and for what part of the working hours, 365 days per year, this is surely dependable under adverse conditions of flood, drought, and ice.

Public-Welfare Problems

These go beyond the scope of utility commission in its supervision and limitation of scope of development, prevention of cutthroat competition, protection against excessive charges and safeguarding good service; and reach out into considerations of conservation and promotion of favorable environment for good citizenship, and are up to the statesman rather than to the engineer; but the engineer must be on the alert to aid the statesman with facts.

From the point of view of public welfare no sane man can question that it is better to utilize water power now running to waste than to be exhausting the future's store of coal and oil, and therefore it is plain that the Government, in doubtful cases, should turn the scale, if it can, by all reasonable helpfulness. To plead for this we must know how great are the differences in costs between water power and steam power that must be overcome.

No sane man can question that the development of industries scattered throughout the country is better for community life than crowding everything into great cities. In this aspect of industrial development—country village vs. metropolis—electric transmission seems thus far to have been hurtful rather than helpful.

Let us look into this carefully and perhaps we shall come to sympathize with what both Maine and Canada are striving for in their restrictions upon the export of power, although neither may have yet found the best solution for its fundamental problem.

Surely, as good citizens jealously guarding the future of our country, we should study these hydroelectric problems from a longer view than that of merely capitalizing a power site for the quickest return to that promoter who wakes up first to its value.

Let us hope that some one with an extremely long range of vision can find justification for the millions of taxpayers' money recently expended at Muscle Shoals.

Value of a Water-Power Site

As to the value of an unused power site, or "mill privilege," as it was called a half-century ago, the public is mostly misinformed, or uninformed. Commonly there are two sides to be considered and weighed in all of those cases where public ownership of water right river bed, or reservoir lands is needed for the development.

Such cases may raise four important problems:

1 What price should the state receive (*a*) from a public-service corporation under state supervision as to rates and service; and (*b*) from a private manufacturing corporation under no particular restraint? Should there be a difference?

2 Should the state block the enterprise until the time is ripe for a development by public funds, owned and managed by public officials (i.e., political control)?

3 To what extent should the state promote hydroelectric development by public or by private means (*a*) for the purpose of conserving a supply of coal and oil for posterity and (*b*) for the purpose of later developing new industrial communities in country districts, away from the great cities?

4 The conservation of the limited supply of capital and labor for use where it will do the most good.

Those who represent the public in legislative halls often seem possessed of hazy and ill-defined views on all of these matters, and engineers may well give liberally of their time in a campaign of education as a highly useful patriotic service.

There is a widespread notion that almost any waterfall can be turned by hydroelectric development into a never-ending, ever-flowing stream of gold, with small understanding of the amount of capital that must be buried beyond recall in such a venture, and on which interest must be paid or income found if capital is to be conserved.

Those who talk of the public's being robbed of its birthright by turning over for a nominal price or rental the potential resources of flowing rivers at rapids or falls to great, soulless corporations, mostly seem to have done neither clear thinking nor accurate estimating, nor to have made a close study of any particular real prospect. There may be circumstances where if a new industrial center or community "in a green country town" can be founded by coaxing capital to take the risk of a new power development, the state or nation may wisely remit all rental price for whatever the public owns that stands in the way, from motives like those that lead enterprising boards of trade to offer free sites and even subsidies to attract industries to their town.

Nor do many of these who talk loudly about development by public funds from taxation and operation under public officials as a source of profit to the public or as a means of stimulating industry by cheaper power, have any conception of the rapid rolling up of compound interest upon those parts of a large investment for whose product there is no immediate customer.

In the great early American power developments at Holyoke, Mass., Lewiston, Me., and Cohoes, N. Y., the original investors are reported to have lost all or the greater part of what they put into these developments, because of fixed charges and operating costs accumulating while waiting for customers to absorb the output. I heard the venerable Charles S. Storrow, treasurer and first engineer of the great water-power development at Lawrence, Mass., testify that they "paid one dividend on expectations and then passed thirteen on facts," while waiting to sell that portion of the power left over after supplying the three great factories built simultaneously with dam and canal.

About 15 years ago, after I had made a careful study and report on the possibilities of power development on a great American river, I was called before a group of about fifteen prominent financiers who had met in the Wall Street district to consider the promotion. My cross-examination was begun by substantially this statement: "Mr. F., there are today 30 to 40 million dollars of questionable water-power bonds floating around this financial district on which it is difficult or impossible to earn the interest; such, for example, as the X Company, the Y Company, and Z Company, etc., etc. (giving names then prominent). For each of these there was a rosy prospect at the time of the underwriting. Now, will you kindly begin by explaining wherein this present prospect differs?"

The answer was to be found in the delays in selling, not in mistakes of engineering. The trouble came in the period that those several projects had to wait before selling the last half of their power.

Hydroelectric development differs from steam-electric development or other power development in that *the big expenditure for water power comes mainly all in one bunch,* whereas with steam it comes step by step, as needed, for almost immediate use.

In water-power development the site, the water rights, the flowage, the dam, the power-house foundations, and the larger part of expenditure for turbines, electric apparatus, switchboard, and transmission line must be made in full at the start, and if customers are not already signed up for sufficient kilowatts to pay fixed charges, the prospects are uninviting.

The investor will do well to look backward while the promoter is trying to lead him forward, and study some of the financial wreckage.

Steadfast Flow and Ready Demand

Lack of steadfastness of the water supply spoils many hydroelectric prospects. Ofttimes the investors in a water-power development have been pained to discover later that they must add a steam plant to their investment. Commonly a prospective dam site on a flashy stream has no substantial cash value, save where it can be developed by electric transmission as a mere "coal saver" to some widespread utility system that already has a full quota of engine power, and in such cases the margin of profit on development commonly is not large. The great falls of the Potomac, within 15 miles of the dome of the capital, still remain undeveloped, though often investigated; but doubtless their day of use will come as a coal saver to an existing steam power plant

in the nearby city. The McCall's Ferry development, now called Holtwood, on the great Susquehanna, was a sorry financial venture until tied up to the steam stations of Baltimore Public Service.

On a variable stream it may be that great reservoirs can be built to regulate the flow, but there the large cost of the reservoirs has to be subtracted in determining the value of the power site. Or, it may be where river banks are favorable and not preoccupied by railroads, that, with the increased engineering skill and courage of recent years, a very high dam can be built at a cost of a few million dollars, to create a reservoir close to hand.

The point which I would stress is that, when one looks at a waterfall or rapid, "all is not gold that glitters."

There are hydroelectric sites with many millions of kilowatts of capacity, in the aggregate, still awaiting development, from Maine to California, from Canada to Mexico, but to decide which ones are worth while, and which ones will be merely sink holes for capital, is a painstaking task.

There are today still many magnificent opportunities for power development lying around unused that are practically without commercial value simply because there is today no use or prospect of early sale for their possible output, and there are other vacant opportunities for hydroelectric developments, figuring into millions of kilowatt-hours per year, which have no large present commercial value because of the large cost of supplementing the low-water flow by steam, or because of the vast cost of establishing a reservoir by high dam or otherwise for regulating the flow.

Demand by Chemical Industry

There is a widespread popular misunderstanding about the present demand for water power. Many think there are great chemical industries earnestly seeking hydroelectric power. The chemical engineer of large vision is today looking for cheap B.t.u. far more than for cheap kilowatt-hours.

This statement may seem strange to one familiar with the vast electrochemical industries at Niagara or with the vast use of power for making aluminum out of purified bauxite, until he has done considerable investigating or has tried to find a customer for a big block of power in the chemical industries. Noting that nearly all those great electrochemical industries making aluminum, caustic, sodium, chlorine, cyanide, carborundum, etc., which are now found located along the Niagara Gorge, rest on processes discovered since capital first had courage to develop Niagara power in advance of customers in sight, one might be inclined to prophesy that another similar great development would similarly be absorbed by electrochemical industries.

Before thus prophesying he had best ask just what new large demands of similar kind actually have come during the past 10 or 15 years from the hundreds of laboratories all over the world in which able chemists are making research of a desire to "help the South."

A prominent and successful Canadian chemical engineer told me that at the close of the World War he sought to establish himself in some large line of manufacture of chemical products, and familiar with the vast undeveloped water-power resources in Canada, upon rivers other than the St. Lawrence and requiring smaller first outlay, he sought far and wide for chemical uses for this power, but each time the trail led him away from the kilowatt-hour to the cheap B.t.u. In other words, to cheap coal, and finally he located in the coal fields of West Virginia.

I know of several owners of power sites of great potentiality who have employed able chemical engineers to seek far and wide in science and industry for uses to which these prospective developments might be put, but still each of these rivers, as Bryant said of the Oregon, rolls on, "and hears no sound save his own dashings."

I know where, in Canada, a million horsepower can be developed in blocks of not less than 100,000 hp. at almost unprecedentedly low cost, perhaps $100 per kw. of primary power, if only profitable use could be found for blocks of this size; but until the chemical engineer comes forward with new uses, as perhaps in iron smelting, or new economic processes for fertilizer, or until steam coal becomes worth $15 per ton at great business centers, I fear such sites have no present substantial commercial value.

And as to the demand for big blocks of cheap hydroelectric power to be used in the manufacture of cheap fertilizer, the public and their deputies in legislative halls have become badly befogged and misled, particularly in the discussions about the development of cheap water power at Muscle Shoals. And a fuller explanation may sometime be in order from the U. S. Army engineers or whoever is responsible for putting in about double the turbine capacity that ordinary business considerations would call for on a river of this small low-water flow, or that business concerns have put in proportional to flow, elsewhere on the Tennessee River and on neighboring streams.

This great Muscle Shoals development seems to some of us to be mainly the result of lack of information and diligent propaganda, of a desire to "help the South"—sending good money after bad while hoping to find cheap fertilizer at the end of a rainbow.

The old spectacular processes for the fixation of nitrogen developed by German science and capital in Norway a dozen years ago, with flaming electric arcs 10 ft. long and of 2 per cent efficiency, were long since outclassed by processes in which a mysterious catalyzer, under favoring conditions of great pressure and high temperature, is doing the work with a relatively small call for power. The nitrogen research bureau of the Federal Government with the vast sums they have spent on research should be able soon to clear the foggy atmosphere that now surrounds the relation of cheap fertilizer to water power.

Value Depends on Use

I have made the previous statements to strongly fix attention on the fact that the value of a prospective hydroelectric site is *not in the water and its fall*, but *solely in the use to which this power can be put* and the rate at which the total output can be absorbed in industry, so as to pay interest upon the capital invested.

If, in a great opportunity for hydroelectric developments, one can obtain firm contracts for, say, half the "firm" or primary output at such prices that he can be assured of bond interest and operating expenses, perhaps he can find capital sufficiently optimistic in faith in the future to wait for its dividends on that part of investment represented by stock. The investor's hope of "velvet" in general must rest mainly on expectations of future sales and on growth of the country, growth in habits of luxury, more illumination, and performing more and more of menial tasks by electricity. All these surely are coming. One who studies the yearly load curves of any great system will marvel at the rate of increase in current consumption from year to year in a district long since seemingly equipped to saturation. But the engineer must seek through most careful analysis to learn *just* where and *just* how fast the increase on his "prospect" is coming.

On the other hand, many who urge conserving nature's fuel resources for posterity seem to have not weighed the importance of also conserving capital for more immediate needs, and the importance of investing the limited supply of available capital where it will do the country the most good.

Conservation of Capital

This frequently is forgotten by those who most loudly urge conservation of natural resources.

Conservation of capital always should be considered along with the conservation of natural resources throughout the design. This frequently will lead to a departure from the line of engineering development that would be ideal at a given site, because of the menace of an unsatisfied interest charge upon capacity provided but not promptly put to use.

It is painful to a good engineer to see only the most cheaply developed part of a great power site cut out and occupied. Sacrificing part of the fall, or sacrificing much of the flow of a variable stream for eight or nine months of the year, may be repulsive to one's ideals, yet frequently there is no other way in which financial loss to the investor can be avoided. Stating the case in another way, unless this done, development at any profit must be definitely postponed, and all of this water and fall continue to run to waste. In such cases the *rights of posterity to the full conservation of this natural resource should be guarded by a time limit in the franchise*, with provision for review at the end of the term.

A sinking fund will sometimes afford a remedy and works may be laid out on such lines that after 20 or perhaps after 40 years the saving made at sacrifice of full utilization, in view of present high

rates for procuring capital (often amounting to 8 per cent or even 10 per cent after brokerage and interest during construction), will, by compounding to the end of this period, permit of highest conservation. The interests both of the country at large and of the investor may be manifested by such a course.

Having made the foregoing statements regarding site value, public welfare, and conservation of capital by way of introduction, we may now consider in more detail a few of the fundamental problems in hydroelectric design and the questions which these involve. Nearly all of these questions lead to, or center around, economics.

Some Preliminary Problems

When a site is presented for consideration, the line of analysis ordinarily is as follows:

1 What is the maximum power in kilowatts that the site can be made to produce economically, and the number of kilowatt-hours per year?

2 What is the size of the successive steps, in which this total development may best be made?

3 What is the accessability of the site; its distance from established centers of industry, or of population; or its proximity to raw materials that can be manufactured by its use?

4 How variable is the natural flow of water and how variable the fall, day by day, and year by year; to what extent can this be regulated?

5 What are the requirements of stream reserve, or the needs of interconnection by long-distance electric transmission lines to other sources, in order to provide for given amounts of primary power, i.e., power that can be depended upon day by day, year after year?

6 What are the prospective load factors, daily, weekly, and yearly?

7 At what rate will the present or prospective market absorb this output? How large a paying load can be taken on at the start? How many years will be required to absorb the entire output of the first stage of development? How long will it take to absorb the entire output proposed?

8 What particular form or sequence of development will be most profitable, sacrificing (if need be) efficiency to lessen first cost, but with works so laid out that the savings thus made, it put into a sinking fund, could ultimately be used for complete development of highest efficiency?

Centralizing vs. Scattering Industries

Hydroelectrical development of the past 25 years presents a fascinating picture, but let us not forget there is something in the nature of a seamy side. Its work so far has mostly been in methods opposite to those by which in the old days a water-power site became the center of a new community under conditions that make for wholesome home life and good citizenship.

The country life and the citizenship on which our future must be established are found at their best in those small cities and villages of the New England, Middle and Mid-West States, built up around industries driven by the small water powers. Brunswick, Maine; Exeter and Claremont, New Hampshire; Springfield, Vermont; Fitchburg and Orange, Massachusetts; Thomaston and Waterbury, Connecticut; Dayton, Ohio—one could name by the dozen communities founded on water power while going over a map of the older states and out to the "Western Reserve," even to Minneapolis and Lawrence, Kansas, to Spokane and Oregon City.

Although, as stated a moment ago, water-power development got a tremendous impulse about twenty-five years ago from an electrical distribution of power and the possibilities if carrying the power over a long distance for immediate sale in enormous blocks to replace steam power in public service of lighting, street railways, and power for minor industries, thereby assuring immediate income sufficient to carry fixed charges, hydroelectric power has built up a new industry in but relatively few places, and seldom has it been the foundation of new neighborly community. Seldom has a hydroelectric development found employment for more men; so far it commonly has lessened the total number of men employed, when miners and stokers and ash handlers are counted.

While this reaching out from a prospective water-power site to the established steam central station of some distant city is surely the best road to a quick income, we may well pause and ask if there are not many cases where the future of our country would be better served by keeping the hydroelectric power at home and providing it only with short transmission lines for driving local industries. Sometimes it may be best for public welfare in the long view to make haste slowly and wait for the industry to appear or for the local "Board of Trade" to find it.

Have we not been led too fast by promoters desirous of a quick profit or by manufacturers who did not see the preservation of old-time American standards of greater importance then the temporary success based on cheap immigrant labor?

Electrical transmission of both steam and hydro power is now helping greatly in the economical establishment of new industries, but up to date it has been favoring further concentration in cities. It would be well if something could be done to start a movement in the opposite direction. As the network of power lines becomes more and more interconnected with the smaller communities, giving to them an ample supply of cheap and dependable power many kinds of industry might again turn to the country village, attracted by lessened real-estate values, fewer strikes, lesser taxes, and by those benefits difficult of precise appraisal that come from the wholesome conditions of family life and social privilege that may be found by operatives in the smaller communities. A wire can carry current in either direction, and there are many cases where favors could be shown by the public in smaller burdens of taxation, etc., etc., that might turn the scale. While things are moving rapidly in relation of the public to power development, harm may come if those who lead the movement are not well informed.

Education in Public Relations

As the speaker said in beginning, these problems of public relations are becoming the most fundamental of all the problems of hydrolectric development.

After prolonged taking of testimony and discussion we now have the Federal Power Act, permitting and encouraging power development from rivers flowing through the public lands of the Great West. Before obtaining this some very intense misunderstandings had to be cleared up. It seems to be working well.

The Ontario Power Commission is trying out public ownership and distribution of power on a gigantic scale, and its results have been widely discussed, pro and con. Perhaps it is too early to judge of it wisely until its secondary effects in building up industries are better established.

The San Francisco City Government recently has gone on record 13 to 2 in favor of municipal distribution of 40,000 hp. of Hetch Hetchy power, with but small understanding of what this would cost, of the influence of varying loads, or the requirements of steam reserve in the city, or the needs of interconnection for emergency service, or of how all these could be accomplished for the best interests of all concerned. The speaker was challenged when there recently by a reporter out for "a story," to defend, if he could, the outrageous greed of a corporation that would offer the city only a cent per kilowatt-hour at wholesale, while he (the reporter) was charged 8 cents at his home. He could not believe that their present power companies in the San Francisco district now or recently had sold power to each other wholesale at three-quarters of a cent per kw-hr.

One of the great problems of water-power development is the education of the general public to understand the costs added by overhead, by steam reserve, by peak loads, by stand-by charges, and by distribution to the small consumer, by the expenses of measuring his draft, collecting his monthly account, and of developing in large blocks safely ahead of the demand, by maintaining a readiness to serve during drought, storm, flood, or fire, by elaborate interconnections with various widely scattered plants.

California, at about the time of last year's elections, was shaken more than by any earthquake over the question of whether or no the state should bond itself for 500 millions of dollars for development or acquisition and distribution of hydroelectric power, and although this was defeated 2 to 1, those whose seismographs are in adjustment say the same question is soon coming up again.

Some years ago the governor of a great state, himself a man of small vision, blocked the beginning of a new industrial city in a sparsely settled corner of his state by canceling the terms of a lease of river bed and dam site to a great power company, on the

grounds that the price per horsepower agreed upon with preceding governor of the opposite political party was insufficient, and that the public was thereby to be robbed. He seems to have failed utterly to have vision of the benefits that come from changing a cow pasture, remote from town or village, into a hive of industry, surrounded by a thousand cheerful homes, and of the risks to be run by some millions of capital in making the proposed development. Thereupon the corporation established its industries in another state.

New York State has by recent referendum voted 2 to 1 against permitting a microscopic proportion of its state lands to be flooded for water-power reservoirs and by this act also has forbidden place and passage for power house and transmission lines upon its forest preserves; an action strangely at variance with the recent policy of the National Government. There appears to have been an inseparable mixture of motives in this large adverse vote. The nature lovers seem to have been inflamed by wealthy owners of private forest preserves—and with some show of truth—against permitting such frightful blots on a beautiful landscape as have resulted in Maine and elsewhere from flooding forest or sprout land without first cutting and burning trees and brush to within a foot of the ground; but the most powerful motive seems to have been a broadly cultivated idea that this defeat would preserve a great opportunity for water-power development under state ownership, with *no real understanding of the facts by the voters at large.*

Ten years ago I worked with the New York State Water Supply Commission diligently for two years in organizing surveys for the fostering of reservoir development by the state for aiding the development of power, and from intimate knowledge of some of these vast opportunities for saving fuel and contributing to industrial development, it is unbelievable that the state will keep them in idleness many years.

The delay will not be all to the bad if it is employed to work out plans for making these power sites contribute to building up small, scattered communities. Using the reservoir water solely for pulp grinding at the rate of 100 hp. more or less per workman is not its highest use, neither is the mere transmitting of it to save coal, or to supply factory power, in cities already far too big for good living conditions.

Recently our Federal Government has shown a most wholesome interest in these large problems of hydroelectric development by promoting the Eastern "superpower survey," and recently Secretary Hoover, of the Department of Commerce, has given this important matter a new impetus. Those problems will be dealt with by the speakers who follow, and I hope the distinction between a superpower system and interconnection may be made clear, but I cannot refrain from quoting briefly from Secretary Hoover's inspiring address before the public utility commissioners of ten eastern states, in New York a month ago. He is reported to have said:

> Engineering science has brought us to the threshold of a new era in the development of electric power. . . . We can now undertake the development from cheaper sources farther afield. . . . We can effect great economies through the interconnection of local systems. . . We can assure more security from the effect of coal strikes and from interruption of railroad transportation. . . Engineers report that more than 40 per cent of the railroad mileage of these eastern territories could be electrified at substantial economies of operation. . .the indirect results both human and material are even more important. . . One of the first principles is the free flow of power across state lines. . . . Physical barriers and other conditions naturally divide the United States into several distinct zones, one embracing New England and the Middle States, another west of the Alleghanies, etc., etc. . . . The problem of each of these sections of the country is different and must be solved separately.

At the recent Richmond Convention of the American Society of Civil Engineers there was presented an extremely interesting and instructive talk by Mr. Wm. S. Lee, Mem. Am. Soc. C. E., on the present widespread interconnection of power systems in the Carolinas and other southeastern states, showing how this widespread benefit of a superpower system came mainly from the transfer of power in a great chain of systems *not by a long leap from one end of the system to the far-distant end*, but by passing surplus from one system merely *to the next in line;* in time of flood, drought, or breakdown, or in finding temporary use for the surplus of a new plant in helping an overloaded neighbor until he too could build larger, and how all of this was in the interest of the public.

Can any reasonable man, familiar with the facts and with human nature, doubt that these far-flung developments can be most rapidly advanced and best carried on by great corporations, under a carefully guarded governmental supervision, better than as an enterprise wholly in state or federal hands and largely dominated by politicians?

Things have now come to the stage where the most fundamental problem of hydroelectric development is the education of the public by making plain the facts.

What Next?

Today it seems that we must be close to the summit, in size of power units and in economy of performance, in both hydroelectric and steam-electric; with line voltage of 220,000; steam at 1200 lb. pressure; water wheels under 3000 ft. head; hydro turbines at 840 ft. head, and single units of 60,000 hp. in water and 80,000 in steam. Surely 94 per cent efficiency on a hydro turbine can never be excelled.

At the Chicago Meeting of the Am. Soc. C. E. last July, Mr. Abbott, of the Chicago Edison Co., who perhaps has supervised the sending out of more kilowatt-hours than any other one man in the world, figured out that it was cheaper to haul coal in cars than to take power over a wire from a station at the mine where the distance was more than 100 miles, at 75 per cent load factor and Mid-West coal costs; and presented a table showing that as between steam plant in city, with coal coming 200 miles on cars and a total of 100,000 kw. capacity costing $12,000,000, and a hydro plant with 200 miles' transmission costing in all $25,000,000, the cost of power delivered, in fuel and overhead for the steam plant, would be about 3.5 per cent smaller for the steam plant than for the hydro—under Mid-West coal prices and conditions. Mr. Junkersfeld, speaking after Mr. Abbott, held out prospects of cheaper long-distance transmission at 300,000 or 350,000 volts within 10 years, and Mr. Hamilton, also of great experience, said in effect that very few hydro developments have been made that can compete with the 5-mill power cost in the best and most favorably placed steam stations.

The only pathways open for further advance seem to be in higher pressures for electrical transmission over distances more than 250 miles, as from the St. Lawrence to New York City, and we have heard rumors that direct-current transmission has some things in store for the future, and then there is the possibility of some new and more efficient form of heat engine.

Who can tell how long the call for this long-distance transmission is to be held back by the success of the mercury-vapor turbine and by the success of those new steam turbines at 1200 lb.? I think it was old Hosea Bigelow who said, "It's dangerous to prophesy unless you know." Just what do we now really know?

The fact that our best reciprocating engines take out or deliver only about 16 per cent of the energy in the fuel, the best of the recent giant steam turbines only 18 per cent to 19 per cent, and the internal-combustion engine perhaps at best less than 40 per cent, offers plenty of scope for fame and fortune and for that joy of conquest which is irresistible. We are told that theory and tests of the first fairly large machine show that the mercury turbine in combination with its steam-turbine partner will cut coal consumption per kilowatt-hour nearly in half.

We have seen the "triple thermic motor," the gas turbine, the Humphrey gas pump and others start forth with rosy promise, stagger and fall by the wayside; but the present case is far from hopeless and the future is indeed full of promise in two particular directions.

Just now the mercury-vapor turbine in combination with steam turbine of 3000 hp. at Hartford[1] divides attention with steam put into a turbine at 1200 lb. per sq. in., or as near to red-hot steam as containers of known metals can withstand.

Will the next great advance come from these improved heat engines or from improvement in long-distance electrical transmission? This brings us forthwith into the discussion of transmitting power to Boston and New York from the St. Lawrence.

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[1] As showing the advance in scale of experimenting, it is worth noting that the horsepower of this mercury-vapor turbine at Hartford is about double that of the great Corliss engine at the Centennial Exposition of 1876. For description of this turbine, see *Electrical World*, Oct. 13, 1923.

St. Lawrence Power

As to bringing St. Lawrence power to Boston, one of the most experienced among the builders and managers of large electric-power developments in America, an engineer who is familiar with electrical power developed in the large way from both water and steam, has recently told me that as a result of careful investigation he believes there is no money to be saved by bringing hydroelectric power to Boston from the St. Lawrence. He finds that turbo units of 30,000 kva. using steam at the recently proposed pressures of from 500 to 600 lb. per sq. in. at location on the Massachusetts seacoast, with coal even at the high prices of 1923, can deliver power to the bus bar just as cheaply as power can be delivered into the Boston circuit from a water-power station on the St. Lawrence, and with the advantage of less risk to interruption, and with the further advantage of smaller initial capital investment; avoiding particularly that in a transmission line for 200,000 kw., which, with its right of way, would itself cost about $50,000 per mile, or from ten to fifteen million dollars at the start!

Other very eminent engineers and financiers are just as strong and clear in their opposite belief, that under present-day conditions, *when account is taken of possible sales along the way*, in a block of, say, 200,000 kw. (perhaps smaller), power could be delivered to the Boston district from Canadian water power at substantially less than the cost of steam-electric power with the most modern type of plant.

Two separate groups of financiers and engineers for some months past have been independently studying ways and means and details for developing and delivering Canadian power, one group proposing to bring power to greater New York district from near the Long Sault on the St. Lawrence, while the other group proposes bringing power to the Boston district from the Ottawa River, close to its confluence with the St. Lawrence. And it is stated by a representative of one of these groups that they can put their hands on the necessary funds whenever the international and interstate questions of law and franchise have been satisfactorily settled.

The bringing of power into New England from even farther back in Canada has been actively discussed. It has even been proposed to transmit the surplus available from the Saguenay development at Grand Discharge, after satisfying the local demand for about 200,000 hp., in the vast pulp and paper mills now being built there, for both mechanical power and the generation of steam for all requirements, by water power in electric boilers.

Obviously, with so vast a local use ready to meet the fixed changes and maintenance of a power that can be developed in large units under high fall at abnormally low cost per horsepower, and with a large surplus flow of water, said to be enough for 200,000 hp. beyond local requirements, these rare circumstances may present a condition of a great block of power so abnormally cheap that an abnormally large percentage of loss in transmission may be allowable, and that an abnormally high transmission from water otherwise wasted over the spillway.

Propaganda and Fog

Within the past two years there has arisen a great propaganda for power development resting upon factors far outside a strict comparison of solely the cost of water power in blocks of 100,000 or 200,000 hp. carried nearly 300 miles, compared with cost of steam-electric power developed nearby at the seaboard.

The farmers of the Western United States and those of Western Canada have united in a plea, which politicians, Congress, and Parliament perhaps may be unable to resist, for a damming and deepening of the St. Lawrence for the double purpose of the passage of ocean-going wheat ships from Lake Superior to the Atlantic, and the development of vast quantities of water power.

It seems that the farmers expect the water power to so largely reimburse the governments that the improved water transportation would be mostly a clear gain to the two nations sharing the cost of dams, canals, and dredging. Of course they assume that like the Canadian canals and the American canal at the Sault Ste. Marie, there would be no tolls.

Since the price of wheat from all over the world practically is fixed in Liverpool, the farmers hope that with the cheapened transportation thereby given, and with no tolls, this increased facility and reduced cost of shipment would give them a 10 per cent increase in the selling price of their wheat in the home town.

Meanwhile, also, the power promoters appear to hope that, with the two governments once firmly committed to financing (or guaranteeing) this vast project and with the money thus placed beyond recall, the opportunity for development of power created incidentally at the new dams and canals around the rapids, would after a time be leased at an almost nominal charge, rather than allow these great national resources to run to waste; and that thereby the vast surplus beyond local needs of water power from so cheap a source could easily bear the burden of 300-mile transmission.

Obviously, if the taxpayers at large of the two countries are willing to foot all the bills, and omit all ship tolls *in addition to increasing the price of bread for their own people* in proportion as the farmer gets nearer the Liverpool price for wheat, this would be fine for cheap local power and at small risk to the farmer. And *perhaps* ways can be found to bring this so cheaply to greater Boston and greater New York that it will cost delivered, say, $^1/_5$ of a cent per kw-hr. less than steam power generated at Fall River, Boston, or New York from sea-borne coal or oil. This exceedingly small fraction—about one-eighth ($^1/_8$) part of the factory cost of power, or about one fiftieth ($^1/_{50}$) part of what the householder pays for his lamp light, seems about all there is in it for the average man in Boston or New York. The public mostly fails to realize that the greater part of the cost of electric power becomes attached to it after it leaves the bus bar or the central station.

There has been a lot of designing in outline, and much estimating and reporting to certain large corporations, and it would be extremely interesting if the details of these plans and estimates were open to public examination and intelligent criticism. The great captains of business, banking, industry, and transatlantic shipping who dominate the chambers of commerce of Montreal and New York, seem far from being convinced that the published estimates of cost of all of this extensive river improvement are on a sound basis, or that any such benefit to the farmer in increased price of wheat could come, although no tolls whatever were imposed for the use of these enlarged canals. Indeed, some say that a saving has been promised greater than the entire present cost of wheat shipment from lake to seaboard.

So far as I can gather from personal discussion with business men and engineers familiar with the situation, the general impression is that last year's report of the International Commission was far from being so thorough a study as should be made before either nation accepts the proposed plans or estimates as final. Some believe that the actual cost would be double that estimated. Surveys and borings and other new data on cost were meager, and from personal observation I am confident that the alignment of this proposed new waterway was in some localities far from being the best for public interests that a thorough study would disclose.

Whatever may be the present obstacles to developing Saint Lawrence power, I believe it certain as the sunrise that sooner or later they will be overcome; and it is plain beyond all argument that it is better for the two nations that this power be used to conserve the coal supply for posterity instead of running to waste. Nevertheless I fear that 10 or 20 years must pass before any important economy in power cost in New England or around New York City can come from this direction. High-pressure steam, cheaper coal, and perhaps the mercury turbine and the Diesel engine, may delay the day for service 300 miles away.

A great captain of industry told me a year ago that cheap hydroelectric power from the St. Lawrence is ultimately a factor of highest importance in the retention of New England's prosperity as a great workshop for home markets and export trade, and likewise for greater New York. And when electrochemists and physicists have performed what we expect of them, Montreal and Quebec may become the world's great center of electrochemical products exported to all parts of the world!

There is more than five million horsepower now running to waste along the St. Lawrence. It is hard even for an engineer to comprehend what five millions of horsepower of energy means, and difficult to translate it into the terms of every-day life. This is about the sum total of electrical generating capacity today in all the central stations, steam and hydro, of New England, New York, New Jersey,

and Pennsylvania.[1] And this St. Lawrence power being 24-hour power with ample storage for conservation, is equivalent to providing about three times the number of kilowatt-hours per year now used in lighting, railways, manufacturing, chemistry and metallurgy, etc., throughout this vast industrial and commercial region.

How soon do New York and New England need it? What will it cost here? How much can we pay for it? How much of it is needed here? These are its fundamental problems here.

In the neighborhood of Montreal, Cornwall, and Ogdensburg, with short transmission and more costly fuel, the problems are of different order.

Discussion at Hydroelectric Session

THE session at which Mr. Freeman's paper was presented was held Wednesday evening, December 5. The American Society of Civil Engineers and the American Institute of Electrical Engineers coöperated with The American Society of Mechanical Engineers in the program, which was arranged to review the fundamentals that must underlie any successful development of hydroelectric power.

The meeting was called to order by John Lyle Harrington, President of The American Society of Mechanical Engineers, who introduced as presiding officer Lewis B. Stillwell, Past-President of the American Institute of Electrical Engineers.

Before proceeding with the program of the evening, Chairman Stillwell emphasized the contribution of engineering in increasing the wealth of the world by research, by invention, by sound judgment, and by courage. He outlined the responsibilities of the civil engineer, the mechanical engineer, and electrical engineer in hydroelectric development, and commented on recent tremendous advances in the art of electrical transmission.

Formal discussions of Mr. Freeman's paper were presented at the session by Col. J. P. Hogan, representing the A.S.C.E., Geo. A. Orrok, representing the A.S.M.E., and Harold W. Buck, representing the A.I.E.E. Their discussions and an abstract of the discussions submitted from the floor are given in the following columns.

The Study of Hydroelectric Possibilities

By JOHN P. HOGAN[2]

MR. FREEMAN has very ably presented to you the fundamental problems of hydroelectric development and I have been asked to discuss that phase of the problem which is concerned with the need of accurate engineering data before proceeding with the development. It would seem almost unnecessary to emphasize the need for careful and accurate investigation if it were not for the fact that there are in this country today any number of hydroelectric developments which have been financial failures. In fact, the number is so great that it is with considerable difficulty that independent hydroelectric projects can be financed. There are in addition numerous hydroelectric projects and extensions to existing systems which have failed to realize expectations and which have been carried through to a conclusion only by the existing financial strength of the companies undertaking them, and these must be classed as failures from a financial point of view. Some of the failures in independent construction have no doubt been due to disappointment in the market but, in general, the majority of the failures in this class and almost all the failures in the case of expansions to existing systems have been due to two causes:

1 Overestimation of the available water supply, and
2 Underestimation of the cost.

Within the past year I have heard several executives of existing companies state that some of their water-power plants have failed to come up to expectation in power output and I have heard others complain that they had been misled, in some cases grievously, by the cost estimates of their engineers. I have heard a member of a banking house engaged in financing hydroelectric projects state in an offhand way, "I always double the estimates of the engineer." These remarks relate only to projects that have been pushed to completion.

In the experience of the consulting engineer there are for every project which has been completed twenty or more projected and receiving more or less consideration in the engineering and financial world, and in many of them the same faults of overestimation of water supply and underestimation of cost appear. In a promotion the reviewing engineer expects that a rather rosy view of the prospects will be taken by the promoter—and even in numerous cases by his engineer; but in the case of extension to existing systems it is more difficult to understand why such mistakes should so frequently occur, and in the majority of cases it must be admitted that they are due either to lack of fundamental data or to ignorance of the principles involved. If, therefore, what I am about to convey to you in the brief time available appears somewhat elementary, I hope you will realize that we are considering a situation which actually exists and that in many cases the failure of hydroelectric developments to meet expectations has been due to the fact that other elementary principles have been disregarded. I propose to touch only the high spots in regard to estimate of available water supply, including rainfall, run-off, and the effects of storage, and the influence on estimates of cost, of proper exploration, and of the proper evaluation of the uncertain factors.

There are no rainfall or run-off records in this country of sufficient duration to enable an absolute prediction to be made of the available water supply. The best that can be done in any case is an approximation, and the accuracy of this approximation will depend upon the length of record of run-off available together with the contributary evidence on both rainfall and run-off of streams of similar location and characteristics. In cases where no run-off records are available, figures must be based on the rainfall record together with the same contributary evidence. It is possible, however, to determine closely the probable value of the approximate estimate, and both the maximum possible error and the probable error that may be expected from such an approximate estimate. It is also possible from a short-term record to construct a probable long-term record by means of comparison with other long-term records which will give a very much better idea of the conditions that may be expected than the consideration of a short-term record alone. The method of doing this has been ably outlined by Mr. Allen Hazen in the Transactions of the American Society of Civil Engineers of June, 1914.

It is pertinent to mention at this point the variations that may be expected in rainfall and run-off and the value that should be given to short-term records.

In the average stream in New York State the maximum daily run-off may be one hundred and fifty times the minimum daily run-off. The run-off in an occasional year may be 50 per cent greater or 50 per cent less than the mean annual run-off over a long period of years. When we consider that the distribution may also vary greatly in different years having the same total run-off, we see how dangerous it is to rely only on estimates of output based on mean annual run-off, yet it is my experience that over 50 per cent of engineering reports on hydroelectric projects are based on predictions of output for the average year.

Actual experience shows that the mean determined from a 15-year record of run-off will probably be within 5 per cent of the true mean, but that it may possibly be 13 per cent more or less than the true mean.

These interesting studies on existing records suggest that with a short-term record of any given length the expectations over a long-term period of any desired length can be deduced by the theory of probability. The methods of doing this have been elaborated by Mr. Hazen in his admirable paper and I will not burden you further with them tonight, but I do wish to emphasize the fact that in my belief better results could be obtained by the use of these methods than by reliance on any actual recorded average flow. Furthermore, by the use of these methods a much better estimate can be made of the benefit to be derived by storage, and by an extension of these methods even operating diagrams can be prepared for existing reservoirs which will permit the greatest use of these reservoirs over a long term of years.

Of all the factors which have contributed to the financial failure

[1] According to the diagram and table published as a supplement to the *Electrical World* of Nov. 17, 1923.
[2] Consulting Engineer, N. Y. City. Mem. A.S.C.E.

of hydroelectric projects, none has had a greater influence than underestimating costs. I like to think that if enough money is available there is nothing beyond the power of engineers to accomplish. The hydroelectric project, however, is essentially a commercial project for the purpose of making money, and if it fails in this respect it is a commercial failure. From its very nature, involving as it does work in water, it is hazardous, and it would seem the part of common sense to limit the risk as much as possible by determination in advance of the conditions to be met. Even at the best a large element of risk or uncertainty will remain due to conditions that cannot be determined in advance or factors that cannot be evaluated. I will pass over these factors of uncertainty which are connected with the construction work such as the organization and management of the construction forces, the amount and character of the preparatory work that will be necessary, and the actual costs and prices of the various items of the work, with a single caution that prices which apply to one job do not necessarily apply to another in a different part of the country or where conditions are different. This statement may seem elementary, yet how often we see estimates and figures that seem ridiculously low and yet are based on records of actual work done at some other time or place. I am particularly reminded of an estimate of cost of a dam to contain 11,000,000 yd. of earth fill, for which a price was estimated of 11 cents per cu. yd. This was based on an article in the *Engineering-News Record* which stated that earth fill had been placed by hydraulic methods at one of the Reclamation Service dams at a price of 7 cents per cu. yd. Other things to be guarded against in this connection are the conscious or unconscious unbalancing of quantities and prices and the omission of necessary items.

Assuming that all errors due to assumed cost of work were avoided, the chief reasons for excessive cost for some of our hydroelectric projects have been the failure to determine or interpret properly the underground conditions in advance of construction and erroneous assumptions based upon such lack of knowledge. Up to recent years the hydroelectric project which was properly explored prior to construction has been the exception rather than the rule. In some cases this neglect has been so surprising that it can only be concluded that the builders were afraid to find out in advance what they would have to encounter for fear that the project would fail. In other cases it seems likely that the lack of exploration was due to lack of appreciation by the engineer of the possibility of underground exploration and interpretation, and in some cases even the lack of experience with the problems involved. The most prevailing causes today, however, are the difficulty that engineers have in impressing on the owners the necessity for such thorough exploration, and the difficulty of obtaining the necessary money. It would seem almost axiomatic that where expenditures of millions of dollars were involved a few thousand dollars for borings and geological investigation would be a reasonable precaution. However, the proper carrying out of the preparatory work on a hydroelectric development is always expensive. It is non-productive work and returns no immediate revenue, and there is usually a constant effort on the part of the owner or developer to cut down expenses. The engineer must have courage enough to insist that sufficient money be allowed for exploration, and he must be able to convince the owner that it will be profitable either in limiting the risk and thereby decreasing the cost or, in some cases, causing the abandonment of an unfavorable project. The trouble is that he has often been instrumental in causing the owner to spend some money on the project and has frequently underestimated the cost of preliminary work. He is between the devil and the deep sea in recommending further expenditures for borings which by unfavorable results may place him in a position to lose the immediate confidence of the owner.

It should be needless to say that sites of all structures should be carefully explored and that the borings should be deep enough to disclose the true underground conditions. Yet, how often do we see disappointment in construction from borings which penetrate only eight or ten feet into rock, whereas experience shows that a minimum depth of forty feet in rock is none too great. It is needful to call attention to the necessity for careful interpretation of the borings themselves and of the conditions disclosed by them. It is of little use to build a dam if it will not hold water. For the proper interpretation of borings and underground conditions the services of a trained geologist are necessary, as well as for careful and competent inspection of the borings while in progress.

I should be sorry if in stating these fundamental principles I have in any way indicated pessimism toward hydroelectric development. Successful hydroelectric development furnishes a permanent asset to this country. Capital expenditures properly made in hydroelectric plants return revenue for an indefinite period with minimum operating and replacement charges. It is only by such permanent structures that material progress in civilization is made. For these reasons hydroelectric development is in the long run much preferable to steam even at equal cost. It is a fact, however, that ill-considered and unprofitable hydroelectric developments in the past have made it more difficult to finance meritorious projects at the present time, and it is necessary that we profit by the mistakes of the past in order to build better for the future. I have therefore pointed out some of these fundamental considerations in a rather elementary way in order that you may take them into consideration. We are now in a period of expanding hydroelectric construction and let us realize that failure of individual projects due to neglect of fundamentals has had and will have an unfortunate effect upon the whole.

Water-Power Costs Versus Steam-Power Costs

By GEO. A. ORROK[1]

THE kind of a presentation of the subject of water-power development which Mr. Freeman has just favored us with is of great advantage to the profession and more particularly to the people of our country, since the basic principles underlying the development of water power have been pointed out in a clear logical and convincing manner for our edification. I have been asked to discuss that portion of the paper covering the question of the cost of water power vs. steam power, and have been particularly asked to cover the general case of large units and transmission from a distance in competition with steam stations of the mos modern design situated near the load center.

The design, construction, and operating results of large steam plants are well known, and from examples which have already been constructed we can predicate very accurately the cost figures which most probably would result under any given combination of circumstances. We know, for instance, that it is possible today to construct an electric generating station using steam as the motive fluid and coal as the fuel in which the cost will not exceed $100 per kw. installed. We know quite accurately that such a station when supplied with reasonably good coal will have a fuel consumption around 1.1 lb. per kw-hr. when run under the best conditions, and we know the law under which the coal consumption varies with the station load factor. We know within reason the labor and maintenance cost, and assuming our fixed charges at 15 per cent with coal running from $4 to $10 per long ton at the station, suitable curves can be drawn which will show the cost per unit delivered to the distribution system at any given load factor.

For the steam station I have figured on five 50,000-kw. units, allowing one as reserve and using 200,000 kw. as the peak load on the station from which the load factor has been figured. I have used good coal, Pocahontas or equal, and assumed that the installation will be modern in all its details and located where there is an adequate supply of good condensing water. In general the figures given are such as any good engineering firm would be willing to guarantee to its clients.

With hydroelectric power, on the contrary, no such general statement can be made, and a separate and accurate estimate must be made for each and every condition. Sometime ago in the discussion of a problem of this kind I developed a set of curves, Fig. 1, which covered the cost per unit of electricity generated by water and transmitted over a 300-mile transmission line to the point of use, which in this instance was a large city, and these curves are sufficiently accurate for our purpose tonight. The transmission line was figured at $50,000 per mile, and the entire plant was proportioned on the basis of a demand on the peak of 200,000 kw. delivered at the point of use 300 miles away. This

[1] Consulting Engineer, N. Y. C. Mem. A.S.M.E., A.S.C.E.

necessitated 250,000 kw. of installation with no reserve, four circuits, the necessary step-down apparatus, and the high-tension underground cables and other apparatus required to connect up this large amount of power to the distribution system of the city.

As the cost of the installation could only be known in a general way, these figures were made to cover a wide variety of total installation cost per net kilowatt of demand, and the cost per unit was worked out for various load factors from 20 to 100 per cent, or from 1750 to 8760 hours of use per year. With these curves and the curves which were made for the steam station, Fig. 2, the price of which included its connection to the distributing system,

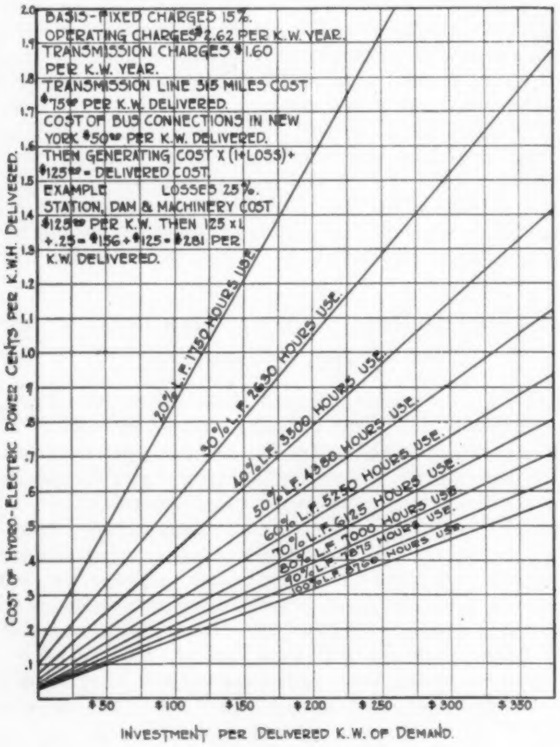

Fig. 1

it is possible to make a rather accurate comparison of the respective advantages of steam power and water power under the conditions stated.

It will be seen that for $4 coal and 100 per cent load factor, corresponding to an output of one billion, seven hundred and fifty million kilowatt-hours per annum, the total costs of steam generated in the large center and water power generated 300 miles away and transmitted to the city are about even when the cost of the hydraulic generating station does not exceed $150 per kw. installed. This point with $6 coal is about equal to $200 per kw. of water installation, and with $8.50 coal to $250 per kw. of water installation. The curves for the steam station are a good deal flatter, however, than the curves for hydroelectric stations, and the various load factors at which the hydroelectric becomes uneconomical can be readily seen from the diagram.

Using the water generation curves at $150 per kw. of installation, it will be noted that as the price of coal increases the load factors at which hydroelectric power becomes attractive decrease. With $5 coal this limit is 83 per cent, with $6 coal about 73 per cent, with $7 coal about 64 per cent, and with $8 coal about 58 per cent, but it will be seen from the curves that about 40 per cent is the low limit for the use of hydraulic power, however high may be the coal price.

It is believed that in the calculations which have been made to construct these curves, a leaning has been indicated toward the hydroelectric side rather than to the steam side, and some of my friends have criticized me for using such a high figure for the cost of the steam generating stations. I also have been criticized for not increasing the $50,000 used as the cost of a four-circuit, 250,000-volt transmission line, but I believe that the advantage has been given in this case to the hydroelectric installation.

Some years ago I had occasion to investigate more than three hundred water-power prospects, mostly in this state. Considerable work was put into surveys and the estimates showed that the installation cost of these powers averaged $450 per kw. Only a very few ran under $200, and none under $150. It appeared from this investigation that coal must approach $10 to $12 a ton before even a small number of these projects would become commercial. But the larger powers of the St. Lawrence and Niagara may possibly figure in the range indicated in the curves and make up for the additional cost of long-distance transmission.

In prewar times, when coal seldom rose above $5 per ton, $125 per kw. of installation was considered as the limiting sum that could be spent on a hydroelectric installation, even where very short transmission lines were involved. With the raising of the coal price as well as the cost of all construction work, this figure may perhaps be as high as $200 per kw. where the market is not far away.

Mr. Freeman has commented on the fact that the use of hydroelectric power in close proximity to its point of generation brings it usually below the cost of steam, but has also shown that the markets for power are almost invariably situated at a distance from the sources of hydraulic power.

Summing up, the curves show the relation between steam generation at the load center and water generation at a distance with coal prices within the range indicated. The transmission cost does not exceed 20 per cent of the total cost of water power and minor variations in distance or cost affect but little the location of the curves, nevertheless water power, even when more costly than steam

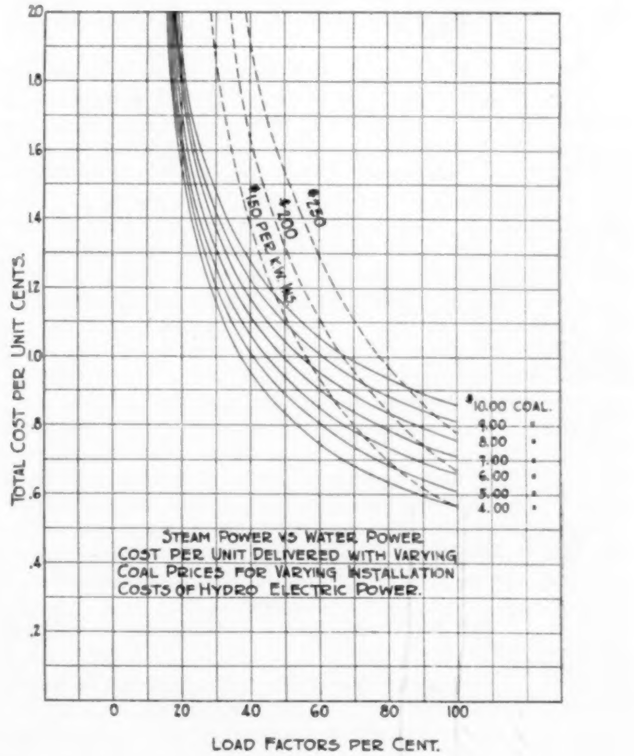

Fig. 2

power, has a place where coal is costly and may be impossible to obtain. The great extension of hydroelectric stations in certain European countries can only be justified by their lack of coal supplies.

Interconnection of Power Systems

By HAROLD W. BUCK[1]

THE question of the distribution of power from water powers is a matter inseparably connected with the enterprise.

One of the greatest movements which is taking place today

(Continued on page 39)

[1] Consulting Engineer, New York, N. Y. Fellow A.I.E.E.

The Salt Velocity Method of Water Measurement

By CHARLES M. ALLEN[1] AND EDWIN A. TAYLOR,[2] WORCESTER, MASS.

This paper describes a new method of water measurement called the Salt Velocity Method. The authors outline the theory and development of the method, describe the apparatus and methods of computation used in laboratory and field tests, give an account of several commercial tests, and present for discussion the claims of the method for a high degree of accuracy and reliability.

THE most accurate known method of measuring water is by weighing, but this method is limited to comparatively small quantities. Other methods which have been used with varying degrees of accuracy are floats, the weir, current meter, pitot tube, venturi meter, color velocity, moving screen, and chemical methods, and the Gibson method.

For many power plants and particularly the recently designed low-head plants with short concrete penstocks of varying cross-section, all of the above methods are too expensive or too inaccurate, and none of them is universally recognized as a standard for field testing. All of them possess inherent disadvantages under various conditions present in commercial tests. For some time a growing need has been felt for a simple and accurate method of measuring water under the above conditions, and the salt velocity method has been developed to meet those conditions as well as the conditions found in long penstocks.

The salt velocity method of water measurement is based on the fact that salt in solution increases the electrical conductivity of water. Salt solution is introduced near the upper end of the conduit, and the passage of the solution by one or more pairs of electrodes, at other points in the conduit, is recorded graphically by electrical recording instruments. The passage of the salt solution between two points is accurately timed, and the volume of the penstock between the same points is accurately determined. The discharge in cubic feet per second equals the volume in cubic feet divided by the time in seconds.

So far as is known by the authors, no successful application of this method of measuring water has ever been made previous to 1921. Early in that year the development of this method was commenced with laboratory tests at the Worcester Polytechnic Institute. In September, 1921, the first commercial tests were made on two units of a power plant. In 1922 the authors conducted extensive investigations at the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute, and at the power plant of the Laurentide Power Company, at Grand Mere, Quebec. In the fall of that year ten successful commercial tests were made. The laboratory investigations and the commercial tests have both been continued in 1923.

1921 Laboratory Investigations

The object of these tests was to investigate the practical possibilities of the salt velocity method. By visualizing an infinite number of floats equally distributed over the cross-section of the conduit, with each little float recording its own velocity and the whole group automatically recording a composite picture of velocities, the theoretical possibilities of this method can be readily understood.

The plant used for these first tests was Plant No. 1 of the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute, Worcester, Mass.

The water supply for this plant is from two ponds with a combined area of 200 acres, and a constant head can be maintained for long periods. A total fall of 35 ft. is available.

The penstock is a 40-in. steel riveted pipe about 350 ft. long. In the laboratory are located a 36- in. by 16-in. venturi meter and an 18-in. horizontal water wheel discharging into a tailrace, at the lower end of which is a 10-ft. standard sharp-crested weir with end contractions.

In these tests, as in all subsequent tests, the apparatus in general consisted of a salt injector and electrodes in the penstock, together with signaling and timing devices.

In the very first tests raw salt was introduced into the penstock, the operator punched the stop watch and then ran down the road to the laboratory where an ammeter was connected to the electrodes, and the operator again punched the watch on deflection of the meter needle.

The first improvement in the introduction of salt was the use of a closed metal box containing a charge of salt which was lowered to the mouth of the penstock by a pole. The charge of salt was released when the hinged sides of the box were raised by wires operated from a platform over the head gate. Raw salt or solution was also placed in paper bags tied to a pole, and when lowered to proper position the bags were broken by a sudden motion of the pole.

Later in the year the salt was injected in the form of a solution piped from an elevated mixing tank over the head gate. A 2-in. pipe led to a quick-acting valve which was operated by a rod from the surface platform.

The first pair of electrodes used were thin strips of copper, 38 in. long, 2 in. wide, and spaced 2 in. apart by wooden blocks. These electrodes were placed in a horizontal position across the center of the pipe and held in place by wooden wedges. A similarly constructed electrode 6 in. long was used for traversing the pipe. This electrode was fastened to a rod passing out of the pipe through a stuffing box and could be held at any position along the diameter of the pipe. Usually during a traverse this small electrode would be held in ten different positions.

Later in the same year several electrodes were made of thin copper strips $^3/_4$ in. wide and 4 in. long, spaced $^3/_{16}$ in. apart. These electrodes were attached to short pitometer rods, rubber-covered wires being substituted for the original pitot tubes. The rods were packed and then screwed on to nipples in front of gate valves. This electrode could be placed in any position across the pipe, rotated to free itself from debris, or withdrawn entirely.

All electrodes were connected by wires and switches to the indicating meters. In 1921 only indicating volt and ammeters were used to record the current between the electrodes. Direct current at 110 volts was used on the circuits.

Soon after the first few tests had been made, a telephone line between the pond and laboratory replaced the running operator. After that the stop watches were started by the operator at the laboratory on verbal signal from the pond operator, and the time was observed at various stages of the needle deflection.

The standard of measurement used in these tests was the 10-ft. weir at the lower end of the laboratory.

Including trials, about 400 charges of salt solution (one charge called a "shot") were used in these tests, which were grouped into thirty runs of from 10 to 20 shots at each gate opening. Runs at each gate opening were repeated six to eight times.

During the 1921 series of laboratory tests, the computation of the discharge by the salt velocity method for comparison with the quantity indicated by the weir was made by three different methods:

1 The time was computed from the moment of salt introduction to the initial appearance of the salt at the electrodes, i.e., the beginning of the curve, and a coefficient 1.095 was computed to give the true Q. This coefficient remained constant for all gate openings and velocities.

2 The time was computed from the moment of salt introduction to the point of mean time between the initial and final appearance of the salt at the electrodes, i.e., half-way between the beginning and end of the curve, and coefficients were computed to give the true Q. These coefficients varied and no constant could be established.

3 The time was computed from the moment of salt introduction to the moment of maximum density of the salt solution passing the electrodes, i.e., the point of maximum deflection

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of the needle or the peak of the curve, and a coefficient was computed to yield the true Q by weir. This coefficient was approximately 1.00 (averaged 0.9975).

These first laboratory trials showed conclusively that the tests could be made and repeated indefinitely with consistent results. They showed an apparent constant relation between the initial

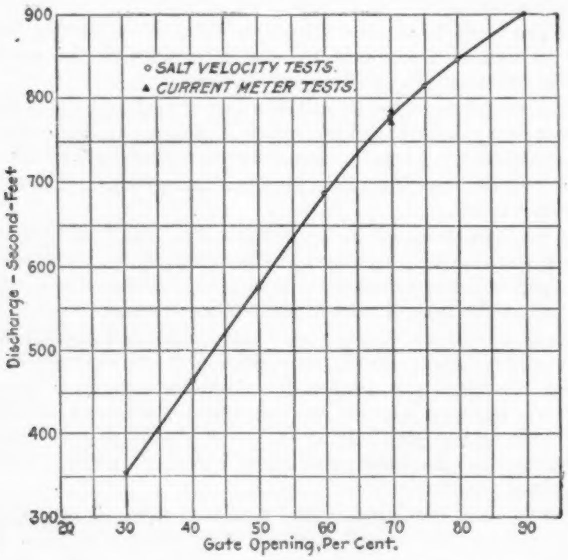

FIG. 1 CURVE OF DISCHARGE OF 13-FT. WOOD-STAVE PIPE, 1400 FT. LONG, UNDER 66 FT. HEAD

appearance of the salt at the electrodes and the time of maximum density of the salt passing the electrodes.

When properly computed the discharge by the salt velocity method checked the true Q by weir within about 1 per cent for single runs and much closer for a long series of runs.

1921 COMMERCIAL TESTS

In September, 1921, tests were made of two hydroelectric units in New Hampshire. The object of these tests was to determine the discharge of each unit at various gate openings. Each unit tested had a penstock of 13-ft. wood-stave pipe 1400 ft. long.

No accurate standard of measurement was used for comparison during the tests, but after the tests two current meters were used and two tests made at the same gate opening, namely, 70 per cent.

The results of these tests were very satisfactory. The work was easily done with very simple apparatus. By reducing to a common head and plotting the discharge against gate opening, smooth curves were the result.

Fig. 1 shows a curve of discharge on gate opening. This curve passes through every test point. The two check tests by current meter are shown at 70 per cent gate, and the salt velocity curve passes midway between them. These two current-meter tests varied from each other by 2 per cent.

These tests confirmed the results of the laboratory tests and showed that the salt velocity method of water measurement was applicable to power plants with long penstocks of uniform diameter.

1922 LABORATORY INVESTIGATIONS

Up to 1922 the method had been used on pipes of uniform diameter only. The Laurentide Power Company at Grand Mere, Quebec, has short, rectangular, converging penstocks, and the object of this series of tests was to determine the accuracy and applicability of the salt velocity method of water measurmeent to that type of penstock.

These tests were conducted at the Worcester Polytechnic Institute Laboratory, but instead of using the 40-in. pipe all the time as in 1921, a majority of the tests were made on the pipe line below the 40-in. section, i.e., through the converging portion of the penstock, through the venturi meter, and through the wheel and draft tube.

The salt introduction was made in a variety of ways, but most of the tests were made with the salt pipe terminating in a pop valve, which operated under pressure and was controlled by a quick-acting valve.

Various electrodes were used and these were wired to a portable Bristol d.c. recording ammeter. Direct current at 110 volts was used. The roll of paper, or chart, for this meter was motor-driven.

The passage of the brine by the different electrodes was recorded on the chart by two pens, each pen actuated by its own meter. The salt introduction was at first recorded by means of a snap switch which was operated by hand simultaneously with the opening and closing of the introduction valve. Later an automatic contact switch was placed on the handle of the introduction valve. These switches were wired to the ammeters with lamps in series for resistance, which recorded the time and duration of the introduction of the salt by either one of the pens just mentioned, on the same chart.

A standard seconds-pendulum clock was wired to the ammeter, and by means of a magnet and relay recorded seconds by a separate pen on the same chart.

The standard for the water measurement was the 10-ft. weir, and the venturi meter was frequently used for check measurements.

Including trials, about 1200 individual tests or charges of salt solution were used which were grouped into 60 runs, and these in turn were segregated into 13 groups based on the stations used for the salt introduction and for electrodes.

The volumes of the penstock between various stations were computed from surveys.

As in 1921, the study of the problem of what point on the curve to use in computing was continued. While recognizing that the theoretically correct center of gravity of the curve should be employed, the exact determination of that point was still too difficult and required too much time for practical use.

The curves made on long sections of pipe continued to be symmetrical and the peaks were used with very uniform and accurate results. The curves made when salt was introduced at Station B and when a short section of pipe with a varying cross-section was used were not symmetrical, and for these curves a few centers of

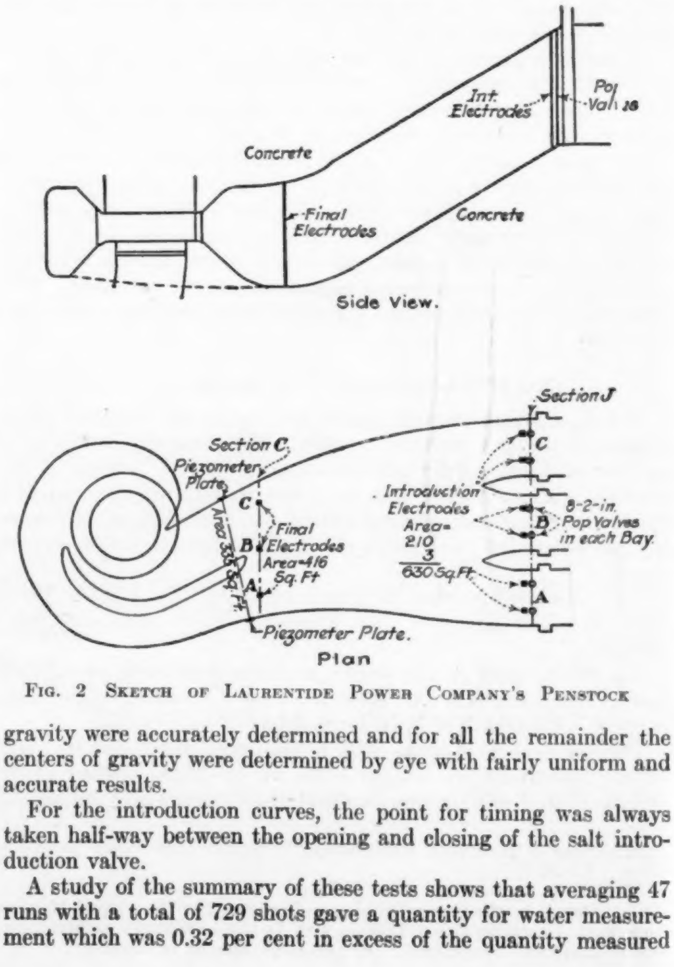

FIG. 2 SKETCH OF LAURENTIDE POWER COMPANY'S PENSTOCK

gravity were accurately determined and for all the remainder the centers of gravity were determined by eye with fairly uniform and accurate results.

For the introduction curves, the point for timing was always taken half-way between the opening and closing of the salt introduction valve.

A study of the summary of these tests shows that averaging 47 runs with a total of 729 shots gave a quantity for water measurement which was 0.32 per cent in excess of the quantity measured

by the weir. Included in these 47 runs are the results with electrodes clear across the pipe, with short electrodes one-quarter to one-third of the diameter into the pipe, with short electrodes in the center of the pipe at the venturi throat, and all traverses across the pipe. The runs omitted from these 47 with accurate results are the runs with short electrodes placed at the center of the pipe at all stations except the venturi throat. The results of these latter runs varied from the true Q by from 3 to 5 per cent, which is to be expected since only the fast water at the center of the pipe was measured and all slow water was neglected.

The traverses were made with an electrode 1 in. long, held at various points along the diameter, and when Q is computed by the equal-area method it varies from the true Q measured on the weir by less than 1 per cent in each case.

These tests showed that the results are accurate and reliable for long sections of penstock, with a short electrode inserted approximately 25 to 30 per cent of the diameter of the pipe. This exact point can be accurately determined by the traverse. The results are also accurate and reliable for all traverses, and for converging or diverging sections of pipe with proper electrodes at proper points in the pipe.

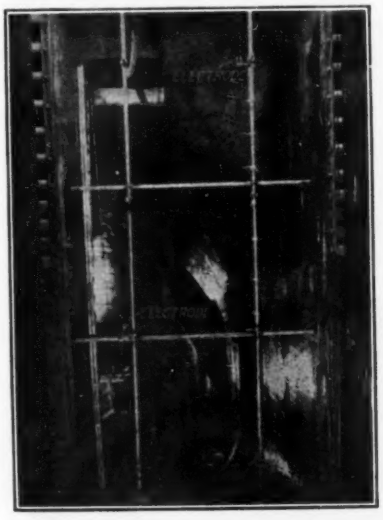

Fig. 3 Pop Valves and Electrodes in Penstock

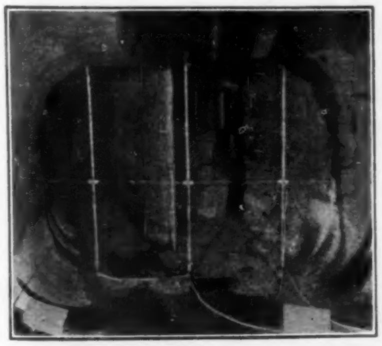

Fig. 4 Lower Electrodes A, B, and C

1922 Field Investigations

Following the laboratory investigations at Worcester in the summer of 1922, field investigations of the salt velocity method of water measurement were made at the power house of the Laurentide Power Co., Ltd., at Grand Mere, Quebec, in October and November, 1922.

The object of these tests was to determine the reliability of the salt velocity method actually applied to short rectangular tapering penstocks in the field.

Unit No. 7 was used for these investigations. The makers' rating of the wheel is 22,000 hp. under 84 ft. head and 120 r.p.m. The penstock is a sloping concrete tube about 65 ft. long, converging from a vertical rectangular cross-section of 630 sq. ft. area at the upper end to a vertical rectangular cross-section of 335 sq. ft. area at the piezometer plates which are located at the entrance to the scroll case of the wheel. The upper end of the penstock is divided by concrete piers into three bays of equal area. See Fig. 2.

In making these tests, from 55 to 57 ft. of penstock (horizontal distance 48 ft.) was used with volumes varying from 27,677 to 28,819 cu. ft.

The apparatus used for the salt introduction was installed in the gate house and consisted of a 500-gal. open mixing tank and a 500-gal. pressure tank. The pressure tank was filled by gravity from the mixing tank which was raised by an overhead traveling crane. A 4-in. pipe led from this pressure tank through a header and equalizer to three $2^1/_2$-in. leader pipes and three lengths of $2^1/_2$-in. fire hose, one hose passing into each bay at the upper end of the penstock.

Each length of hose was connected to eight pop valves of special design located in each bay of the penstock. These 24 pop valves were arranged so as to give a uniform distribution of salt over the entire cross-section. The distribution of brine to these pop valves was controlled by a 4-in. quick-acting valve which had a 30-in. handwheel near the pressure tank. The brine was also controlled by valves at the upper end of each leader pipe. Fig. 3 shows the pop valves in Bay C while the penstock was emptied. Air pressure of 100 lb. per sq. in. was available for these tests.

Various electrodes and signals were used to record the salt introduction, but during the last period of these tests and during the final efficiency tests of Unit No. 7, six pairs of electrodes, placed

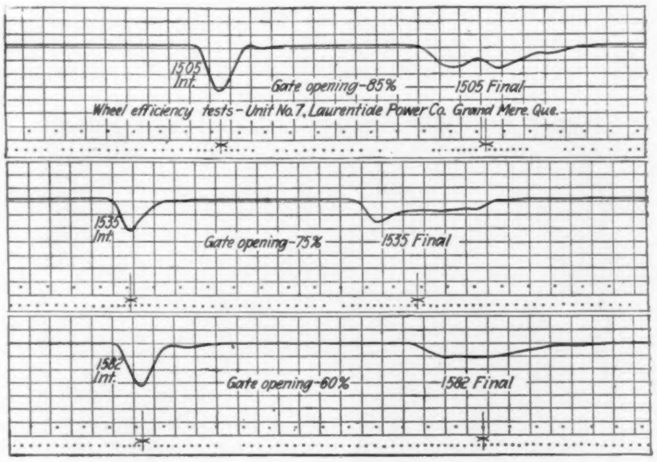

Fig. 5 Sample Curves, Laurentide Power Company Tests

about 22 in. downstream from the plane of the pop valves, were used. These electrodes were made of 4-in. by $^1/_2$-in. steel plate 10 ft. long, placed parallel to the thread of the penstock.

Three pairs of steel electrodes placed vertically at the lower end of the penstock and about three feet upstream from the entrance to the scroll case recorded the passage of the salt at that section. These lower electrodes were made of 4-in. by $^1/_2$-in. steel plates spaced 1 in. apart by horn fiber insulation and with the bolts insulated with fiber and rubber. In later tests the fiber insulation was changed to hard rubber, and finally to porcelain. These electrodes were continuous, extending from the floor to the roof.

Wires with switches connected all of the electrodes to the recording electrical instruments in the gate house. The record was made in three ways: by recording curve-drawing ammeter, by recording curve-drawing wattmeter, and by a special integrating device using a watt-hour meter developed by the engineers of the Laurentide Power Co. Through a standard seconds clock the time record was made by both pen and jump spark.

Including trials and all efficiency tests, about 1800 individual tests or charges of salt solution were used. These were grouped into 220 runs of from five to twenty shots each.

Fig. 5 shows sample curves recording the passage of salt at both the upper and lower electrodes for three different gate openings. All of these curves were made in the November tests after the various electrodes had been changed and improved.

The curves made by these tests were not as symmetrical as those obtained in the laboratory investigations, and the maximum deflections of the meter, that is, the peaks of the curves, would not give accurate results. But the curves were not distorted sufficiently to cause any material difference between the center of area and the center of gravity. During the majority of the tests the point on the curves from which time was computed was the center of area, as indicated by the watt-hour meter record.

The greatest value of these investigations was the demonstration, under field conditions, that the tests by the salt velocity method applied to the setting at Grand Mere could be repeated and checked indefinitely, and that the tests could be repeated with varying apparatus and equipment and with various methods of computation, and still check.

These tests tried out and eliminated several sources of error, and showed that the final apparatus and methods used in the efficiency tests were an improvement over the original apparatus first installed.

With all the various apparatus and methods used the maximum

variations shown in the comparisons were + 1.3 per cent and − 2.5 per cent, with an average variation of 0.1 per cent for the whole. With improved apparatus the maximum variations were reduced.

1922 Commercial Tests

During the fall of 1922, ten successful commercial tests were made using the salt velocity method of water measurement. On all of the tests the object was the measurement of the discharge through the penstock of a power plant. On seven of the tests the discharge values were used in computing the efficiency of the units, on two tests the discharge values were used to calibrate meters, and in the tenth test the values were used for determining the efficiency of

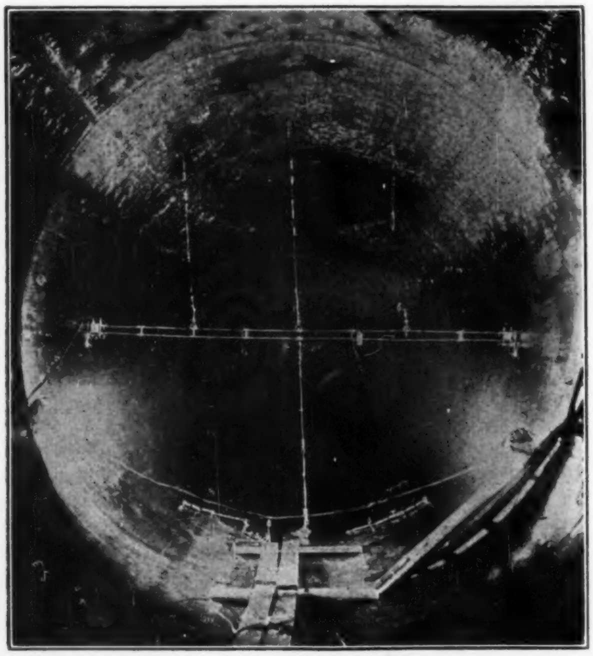

Fig. 6 Electrode Used in Concrete Penstock 20 Ft. in Diameter

the unit and also for calibrating a Johnson valve to be used as a venturi meter.

The plants under test were all hydroelectric power plants. The sizes of penstocks used were:

Two tests	– Riveted steel	11 ft. diameter, 1000 ft. long.
Two tests	– Riveted steel	12 ft. diameter, 500 ft. long.
Two tests	– Riveted steel	13 ft. diameter, 1500 ft. long.
One test	– Concrete	20 ft. diameter, 500 ft. long.
Three tests	– Concrete, rectangular tapered,	10 to 70 ft. long

The apparatus for salt introduction, the electrodes, the meters and the timing devices were all similar to those used at Worcester and at Grand Mere. Figs. 6 and 7 show two forms of electrodes used.

No standards of water measurement were employed on these tests and no other methods except when a meter was being calibrated. At one plant the same unit was later tested by the Gibson method and the final curves by the two methods checked exactly along the range of high efficiency and only varied slightly at the lower gate openings.

The results of the tests on the long round penstocks were consistent and confirmed the accuracy and reliability of the method applied to such penstocks. They also justified the various apparatus and methods of computation used on the rectangular tapering penstocks, but they did not shed any additional light on the accuracy of the method applied to that type of penstock.

However, one of these tests on a large unit in Canada did confirm the accuracy of the salt velocity method on rectangular converging tubes. The penstock for this unit was 500 ft. long with a uniform diameter of 20 ft. and was fed by four rectangular converging tubes and one elliptical diverging tube. During these tests it was possible, at five different gate openings, to compare the discharge measured in these five tubes with the same discharge measured in the main penstock of uniform cross-section. The greatest variation was 0.7 per cent, and the average of all discharges checked exactly. The four rectangular converging tubes were typical of the penstocks at Grand Mere, and this checking of results gave added assurance as to the accuracy of the tests on short rectangular tapering penstocks.

1923 Laboratory Investigations

Following the field investigations at Grand Mere, Quebec, which were completed in November, 1922, another set of laboratory investigations was made at Worcester, Mass., in January, February, and March, 1923.

The main object of these investigations was to determine the degree of accuracy of the salt velocity method of water measurement against the weighing tank, and particularly the accuracy of the apparatus and methods of computation used during the field and efficiency tests of 1922.

A summary of the results of these 1923 laboratory tests shows that for 36 groups, 123 runs, and 1012 shots, Q by salt differs from Q by weight by + 0.05 per cent. This omits trial runs, runs with flat final electrodes, and runs which have been computed with known errors for purposes of comparison, such as peaks and drags.

Analysis for Type of Final Electrode

Electrode	Groups	Runs	Shots	Salt, Per cent
Screen	21	80	547	−0.01
Improved	11	31	180	+0.06
Traverse	4	12	285	−0.09

Q by weight = 100 per cent.

These tests proved that, when properly conducted, the salt velocity method of water measurement checks the discharge by weight,

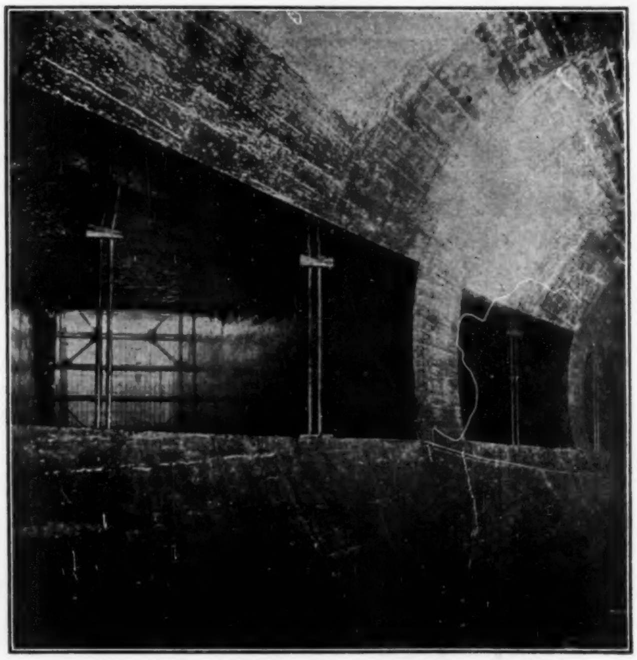

Fig. 7 Electrodes Used in Gathering Tubes

which is the most accurate known method of measuring water. For short pipes the following facts regarding apparatus and methods of computation were proved or confirmed:

That a tight quick-closing pop valve is most suitable for salt injection.

That other methods of salt injection can be used, but correct results are obtained only by applying an arbitrary and consequently inaccurate correction.

That it makes very little difference what form of electrode is used at the introduction when the salt-injection pipe is very close.

That screens or grids are ideal for both introduction and final electrodes.

That an improved plate construction with proper spacing for the final electrodes gives very accurate results.

(Continued on page 51)

The Development of Modern Stamping Practice

Early Uses of Pressed Metal—Pressed Steel in the Automobile Field—Replacement of Cast-Iron Parts by Pressed Steel—Various Applications of Pressed Steel

By W. W. GALBREATH[1] and JOHN R. WINTER,[2] WARREN, OHIO

THE whole progress of man has been dependent upon the discoveries and inventions which he has made, and the greatest single step in this progress has been his discoveries in treating metals to accomplish certain desired ends.

Primitive man had fire at his command at a very early period, and with its aid he was able to smelt ore and then hammer or cast the product thus obtained into various forms. For centuries, forging and casting were the only methods known for producing iron parts. Large quantities of parts were not required and for a long time slow, expensive methods of manufacture prevailed. Many can remember the cast-iron keys and the forged hardware that decorated the doors of homes only a few generations ago. Since quantities were small, there was little incentive to develop methods that would produce parts at high speed and relatively low cost.

Early Uses of Pressed Metal

Then came the development of the electrical industry which grew with amazing rapidity. The old-time gas-chandelier and oil-lamp manufacturers had been content with slow hand methods of spinning the light-weight metal parts that were required. The electrical industry, however, needed speed in the production of thousands of various parts that had to be uniform but usually with only thin walls and of no great size. Electrical manufacturers discovered that these parts could be pressed from steel and brass with amazing rapidity and accuracy.

Shortly after began the phenomenal development of the automobile, and soon the primitive "horseless carriage" was raising the dust of the highways. But the automobile manufacturer followed a very ancient law, the "law of habit." Because he had grown up in the carriage and wagon business where castings, forgings, and wooden parts had been his daily contact, these were the parts he used. The law of habit was strong, but the law of necessity was greater. Many castings were too heavy and too slowly produced. With greater production the automobile manufacturer could see the day coming when he would have to put in enormous quantities of additional equipment for performing the necessary machining and drilling operations required on cast parts. Most important, however, was the demand for lighter weight.

Pressed Steel in the Automobile Field

About this time the man with pressed-steel experience began to seek employment in the automobile field. His early activities in pressed steel for the automotive industry were confined to the lighter parts, such as clips, braces, and brackets. Here savings were accomplished that made it easier to get the automobile manufacturer to consider stamping the heavier parts of his car.

A typical instance of how pressed steel made a saving for one automobile manufacturer in the early days when chain drives were standard practice, is told by a man of many years' experience in the stamping field. This particular manufacturer had a combined sprocket and brake drum for the rear wheels of his car. The part was made from a casting which was expensive, heavy, and difficult to make. But by the proper combination of a pressed drum with a separate sprocket—not so easily worked out as words seem to convey—this pressed-steel engineer designed both a better drum and a better sprocket at lower cost. One can just imagine this manufacturer soon looking over his car for other savings pressed steel might bring.

In the automotive field the first major parts of a car that were pressed in large quantities were brake drums, and then frames and then hubs, and so on until today almost the entire car, body and all, is made of pressed steel.

What to the eye seems a rather simple job of stamping is very frequently a task which requires days and days of study and experimenting. The first brake drums produced were made by two drawing operations and had, as the pressed-steel man terms them, "picket fences." In other words, the edge of the flange was not true, but wavy, nor were the drums always perfectly round. Now pressed brake drums are manufactured by one operation.

Today a brake drum must be round within twenty thousandths of an inch, which in a 14-in. drum is surely a very slight variation from a perfect circle. This tolerance would not be difficult if every piece of sheet steel supplied had exactly the same thickness and exactly the same temper, but this is not commercially possible. This very difference, which cannot be overcome, causes stamping manufacturers the most of their difficulties.

Much thought and effort have been expended on the relatively simple process of pressing drums. One large manufacturer, whose plant turns out mountains of brake drums each year, tells of the obstacles that had to be overcome in producing a particular drum with an unusual profile of various sizes. A contract for making these drums (9 in. in diameter) out of $^1/_8$-in. stock was secured. The dies were made and the job went through the plant without a hitch. Then along came a contract for making the same drums 12 in. in diameter out of slightly heavier stock. Every one expected the work to go through with the same facility as before, but unexpected difficulties were encountered.

Cold sheet steel when subjected to several hundred tons' pressure in a heavy press really flows, or in other words, part of the sheet is stretched to make a thinner wall, and part forced into certain sections to make a thicker wall. In the 12-in. drum the steel did not act at all as it had in the smaller drums and too much metal concentrated at one point. However, after many hours of study and experimenting, perfect drums were finally produced.

But the story does not end here. Shortly after along came an order for 14-in. drums with the same profile and of proportionately heavier stock. With the previous experience on the 12-in. drums it would seem that no new problem could arise. But it did, for the 14-in. drums did not act at all as had either the 9-in. or the 12-in.; and the production of the larger drums had to be studied through just as thoroughly as that of the two smaller ones.

The production of pressed parts of large size requires infinite patience, coupled with a wide knowledge and experience of the action of steel under various conditions and an understanding of why and how each job differs from another. Success in the use of pressed parts can be assured only when this experience is employed. Fortunately, there are today a number of stamping organizations in the country that have this ability.

Another one of the interesting phases of the development of pressed-steel parts for this industry is the replacement of cast-aluminum parts. As previously mentioned, lightness was one of the influencing factors in the automotive industry that pressed steel helped to solve.

Before pressed steel occupied the important place it does today in the automotive field, manufacturers turned their attention to lighter metals, chiefly aluminum, in attempting to reduce the weight of their cars. In many instances, however, pressed-steel parts have even excelled aluminum in lightness, not to mention the additional advantage-saving in costs.

Fig. 1 shows two crankcases. The original cast aluminum crankcase weighed 13.5 lb. while the pressed-steel crankcase which replaced it weighs only 12 lb., or $1^1/_2$ lb. less than the aluminum part it replaced. Both crankcases are identical in size and accomplish

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the same purpose, but the pressed-steel part made a substantial saving in both cost and weight for the manufacturer.

Replacement of Cast-Iron Parts by Pressed Steel

In the replacement of cast-iron parts, pressed steel has effected very many savings, both tangible and intangible, for the automotive industries. Fig. 2 shows two radiator shells used on a well-known truck in which the use of pressed steel saved the manufacturer 35 per cent in material tonnage alone. In addition, many

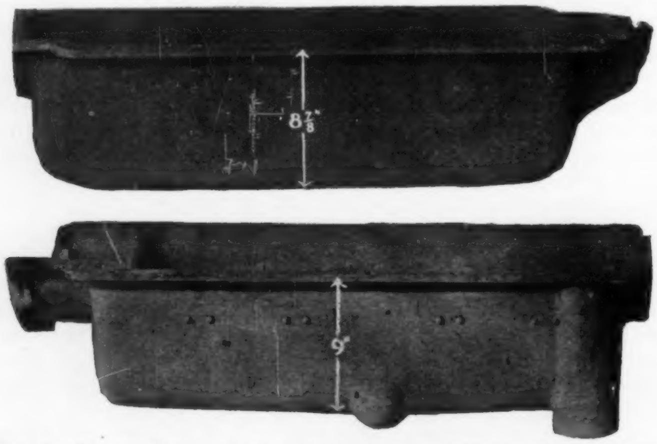


Fig. 1 A Cast Aluminum Crankcase and the Pressed-Steel Crankcase that Replaced It

(The pressed-steel part actually weighs less than the aluminum (12 lb., as against 13½ lb.), although the same size, and was produced at a much lower cost.)

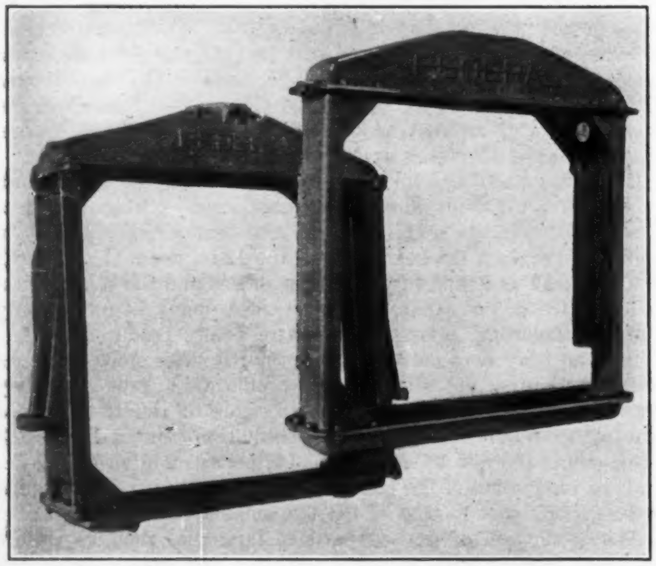


Fig. 2 Left: Cast Radiator Shell Weighing 44 Lb. Right: Pressed-Steel Radiator Shell Weighing 28½ Lb.

machining operations were eliminated and the parts were delivered to the plant ready for assembling. Moreover much less weight had to be hauled both in and out of the plant, as well as by the truck during its whole period of usefulness.

A particularly interesting example of the application of pressed steel to the automotive field is illustrated by the redevelopment of a dual-reduction housing cover from cast aluminum to pressed steel (Fig. 3). By the very nature of the method of manufacture, a cast part is usually one solid unit. All projections, bosses, etc., can be cast as integral parts of the main member. In considering such a part from a pressed-steel production standpoint, it frequently happens that the cast part has to be viewed from its component parts. Here is where the ingenuity of the pressed-steel engineer comes to play. In this dual-reduction housing cover the problem was to provide material for the necessary tapping of the two small openings. This demand was successfully and cleverly met by the insertion of a steel flange and cast-iron elbow, which provided the necessary tapping facilities. While the weight of the whole part was increased very slightly, this was not a vital factor, and the cost of the pressed part represented a very substantial saving over the cast part. Particular attention is directed to this redevelopment, because many parts that at first are apparent impossibilities for pressed-steel redevelopment can be produced by those who are experienced in this work and who recognize that a completed pressed part is often secured by the combination of several different pressed units. The only way of making sure that any part cannot be successfully produced by stamping methods is to submit the part in question to a competent pressed-steel engineer.

Various Applications of Pressed Steel

But while the automotive manufacturer had been building his business through the use of pressed-metal parts and thus obtained not only the required quantity production but was also able to turn out better cars at lower prices because of the savings accomplished, a few other manufacturers made desultory attempts to

Fig. 3 Dual-Reduction Housing Cover

(By replacing the cast aluminum reduction housing cover with a pressed part having an inserted flange and cast-iron elbow welded on, pressed steel save 33⅓ per cent of the cost of the cast-aluminum housing.)

Fig. 4 Cast-Steel and Pressed-Steel Pintle Housings

(Cast housing at left weighs 18 lb.; pressed housing at right, 10 lb. 12 oz.)

apply the pressed-steel idea. During the war, both small and heavy pressed parts were used in enormous quantities. The casting capacity of the country was limited and could not begin to fill the requirements, so that pressed steel met an urgent need.

Pressed-steel shells are familiar to all, but a typical war development of pressed steel is illustrated by a cast-steel pintle housing (Fig. 4) developed into pressed steel. In this instance not only was the saving in weight a strong incentive, when the demand was for conservation, but the difference in method was of first importance, since all casting capacity thus released could be more effec-

tively used on other parts where casting was an absolute requirement.

During the peace-time prosperity which followed the war, many of these manufacturers who had watched the development of pressed steel in the automotive industry and who had seen the war-time use of pressed metal, cast about for less costly methods of securing parts. But the real possibilities had to be brought home by those interested in the manufacture of pressed parts, and unfortunately many manufacturers have been too lethargic in appreciating the value of pressed steel. As a case in point, may be cited the experience of one pressed-steel salesman with a gas-meter manufacturer.

FIG. 5 CAST-IRON AND PRESSED-STEEL INDUSTRIAL CAR WHEELS
(The pressed-steel wheel at the right cut the weight 62 per cent and the cost 50 per cent.)

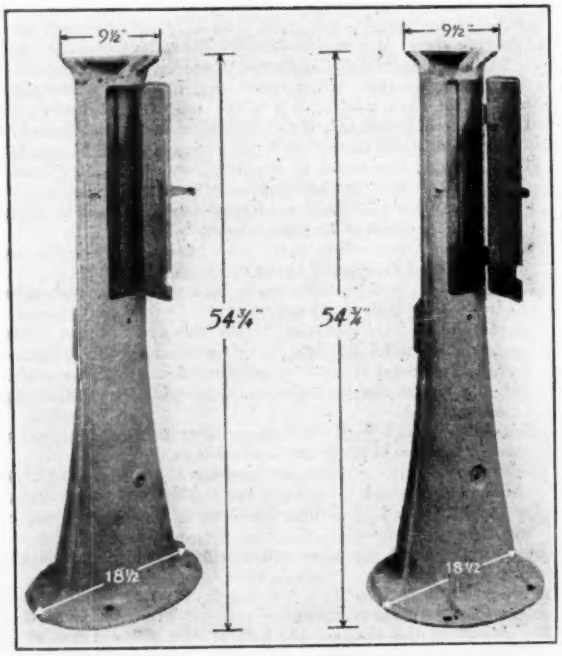


FIG. 6 CAST- AND PRESSED-STEEL GASOLINE-PUMP BASES
[The base on the right is pressed steel and weighs 60 lb. The cast base replaced (at the left) weighs 155 lb.]

Noticing one day that the covers of the meters made by this manufacturer were castings and required a number of drilling and machining operations to secure a proper fit, the salesman paid him a visit and discussed the advisability of making them out of pressed steel. This material did not at first seem to meet the requirements, but the problem was studied and a pressed-steel meter cover designed that not only saved the meter manufacturer many dollars in first cost, but also eliminated a number of expensive machining and drilling operations. In addition, a troublesome problem in breakage of the cast covers was solved by the employment of pressed steel.

One pressed-steel redevelopment, made for a manufacturer of gasoline section cars—the type so often used by railroad track gangs—is a striking example of the weight saving that pressed steel often accomplishes. This manufacturer had been using a cast-iron wheel 20 in. in diameter on the tread and weighing 125 lb. The redevelopment of the cast wheel into a pressed wheel, to which a cast-iron hub was fastened, reduced the weight 78 lb. Of even greater importance was a cost saving of over 50 per cent. Photographs of both wheels are reproduced in Fig. 5.

Many of the gasoline pumps seen at filling stations are definite object lessons in pressed steel that can be applied to the business of a customer provided he uses any cast parts. Take for example the pump base shown on the left in Fig. 6. This base consisted of two cast parts $54^3/_4$ in. high, with a cast door giving access to the mechanism installed in the interior. From the layman's standpoint the base looked like an impossibility for pressed metal because of its great length and the number of minor attachments, such as hinges and door latch, that were an integral part of the large casting. But a pressed-steel engineer who knew how to attack such problems studied the casting not as a whole but in all its various parts, and worked out ways by which these smaller parts could be reduced to pressed-steel possibilities. The results of this study are to be seen the pressed-steel pump base shown at the right in Fig. 6.

Correct design, big, heavy-duty presses, the acetylene torch, and electric welder produced a pressed base made up of twenty-five separate pressed pieces which, when assembled, weigh less than half as much as the cast base—60 lb. of pressed metal against 155 lb. of castings. In addition to the material savings must be considered the collateral savings in freight and ease of handling, as well as the elimination of machining costs and breakage.

Many manufacturers who have learned by actual experience the exceptional advantages pressed steel has accomplished in one part, have carried the saving thus secured to other parts of the same equipment. A stove manufacturer who was induced to adopt pressed-steel legs for his stoves found the savings so substantial that he developed several other cast parts such as door frames and doors into pressed parts. Another feature—of selling importance—was found in the fact that pressed parts take enamel finish better than cast parts.

One wringer manufacturer is now using pressed parts in place of cast parts for all of the metal work on his product with the exception of the clamping screws. A washing-machine manufacturer redesigned his entire machine and kept in close touch with the engineering department of the stamping organization that made his stampings—with the result that he now has a machine that uses pressed steel most effectively and presents a much better appearance.

The opportunity of getting a better product with stronger selling points can be secured by many a manufacturer in the household-appliance field if he will but get in touch with a competent stamping organization. A gasoline-pump manufacturer who had had previous gratifying experiences with pressed steel, was considering the manufacture of an oil-tank truck. Ordinarily his own designers would have planned the entire job, but his confidence in the pressed-steel organization and the results it had secured for him led him to find out first how pressed steel could be used in its construction. The truck, was designed entirely in the stamping manufacturer's plant and every part, except the castors, is pressed metal.

There is scarcely a plant in this country using metal parts that cannot apply pressed metal to advantage, no matter if the product is one of long standing or whether a new product is under consideration.

It is not the aim of the pressed-metal manufacturer to eliminate castings, for there are thousands of parts which are cast that cannot be produced in any other way. But pressed metal is making a wonderful contribution to industry in speeding up the production of parts, reducing excessive unnecessary weight, eliminating many expensive machining operations, and saving material and handling costs, in addition to savings in plant investment that would have to be made to take care of many finishing operations required when cast parts are used. The same advantages which many industries today are getting from the use of pressed parts can be obtained by almost any manufacturer who will get the facts on his own products. The pressed-metal industry is ready and waiting to serve him.

Report on the Present Status and Future Problems of the Art of Cutting and Forming Metals[1]

FOR a number of years the A.S.M.E. Research Committee has realized the pressing need for systematic investigation of many of the problems now confronting the builders and users of machine tools. Most of these are in some way connected with the cutting and forming of metals.

Finally in June it was decided to organize a new Special Research committee to foster research activity in this field. It is not intended that the members of this Committee will carry on the actual research themselves, but an attempt has been made to gather together in one committee representatives of all the groups which have for some time been at work on the various phases of the problems connected with the cutting and forming of metals. In a sense, therefore, this Committee will eventually become a clearing house for information on the subject. It is also hoped that the organization of such a committee by the Society will encourage the industry to place funds at its disposal for specific studies for the support of the general investigation.

Before this Committee devoted its attention to the solution of any of the problems before it, a general discussion of the subject seemed to be desirable. It accordingly negotiated with the officers of the A.S.M.E. Machine Shop Division and it was decided that a Progress Report on the Present Status and Future Problems of the Art of Cutting Metals should be prepared by this Committee and presented at the Machine Shop Session of the Annual Meeting in December.—R. J. S. Pigott, Chairman, A.S.M.E. Research Committee.

Outline of Report

THE various terms used in the art of cutting metals and about which there is such a wide diversity of opinion, should have a positive definition and a statement of their relative information in this field. We are therefore listing the more important terms that have come into use and whose definition is more or less a matter of personal opinion: namely, (a) "Machinability" of work, (b) "Cutability" of tools, (c) "Lubrication," (d) "Cooling," (e) "Durability" (endurance) of tool, (f) "Hardness" of tool and work, and (g) "Tool Performance."

II State of the art in the design of cutting tools and its relation to the character of the work produced and the time required. Pars. 1 to 28.

III Progress made to date in the art of cutting metals, and the value of the following factors:

- a Material composing the cutting tool. Pars. 29 to 28.
- b Material used in testing cutting tools. Pars. 36 to 43.
- c The design of the cutting tool. Pars. 9 to 28.
- d Performance of cutting fluids with respect to lubrication and cooling action. Pars. 44 to 54.

IV Present practice and methods of testing cutting-tool materials and materials to be cut.

V Problems to be considered for research work. Recommendations of Committee. Pars. 55 and 56.

VI Methods of financing the research problems that are to be taken up in the order in which the industry needs them most. Pars. 58 to 61.

VII Summary of research work on the art of cutting metals, giving methods employed by different experimenters. Pars. 62 to 157.

VIII Bibliography of the subject. See statement, Par. 56.

THE STATE OF THE ART IN THE DESIGN OF CUTTING TOOLS

1 The state of the art in the design of cutting tools and its relation to the character of the work produced and the time required, is practically where Dr. Taylor left it twenty years ago.

2 The following, broadly speaking, are the four objects to be kept in mind in the design of a standard tool.

- a The necessity of leaving the forging or casting to be cut with a true and sufficiently smooth surface;
- b Removing the metal in the shortest time;
- c The adoption of that shape of tool which shall do the largest amount of work with the minimum combined cost of grinding, forging and tool steel;
- d Ready adaptability to a large variety of work.

3 However, as we go further into this subject the nature of the conflict between these four objects and of the sacrifice which each element is called upon to make by one of the others is apparent. To illustrate the nature of these compromises:

4 Generally speaking, we have been obliged to adopt as our standard shape a tool which can be run at only about, say, five-eighths of the cutting speed which our knowledge of the art and our experiments show us could be obtained through another tool of entirely different shape if no other element than that of cutting speed required consideration.

5 We have been obliged to sacrifice cutting speed to securing smaller liability to chatter; a rather truer finish; a greater all-round convenience for the operation in using the tool; and a comparatively cheaper dressing and grinding. The most important of the above considerations, however, is the freedom from chatter.

6 On the other hand, we have been obliged to adopt a rather more elaborate and expensive method of dressing the tools than is usual in order to provide a shape of tool which allows it to be ground a great many times without redressing, and also in order to make a single Taylor-White heat treatment of the tool last longer than it otherwise would. And again, the shape of the curve of the cutting edge of the tool which we have adopted—first, to insure against chatter, and second, for all-round adaptability in the lathe—calls for much more expense and care in the grinding than would be necessary if a more simple shape were used This necessitates in a shop either a specially trained man to grind the tools by hand to the required templets and angles or preferably the use of an automatic tool grinder.[1]

7 Now, keeping the four objects mentioned above in mind, let us consider the elements affecting the cutting speed of tools in the order of their relative importance.

8 The cutting speed of a tool is directly dependent upon the following elements. The order in which the elements are given indicates their relative effect in modifying the cutting speed, and in order to compare them, we have written in each case figures which represent, broadly speaking, the ratio between the lower and higher limits of speed as affected by each element. These limits will be met with daily in machine-shop practice.

- a The quality of the metal which is to be cut; i.e., its hardness or other qualities which affect the cutting speed.
  Proportion is as 1 in the case of semi-hardened steel or chilled iron to 100 in the case of very soft low-carbon steel.
- b The chemical composition of the steel from which the tool is made, and the heat treatment of the tool.
  Proportion is as 1 in tools made from tempered carbon steel to 7 in the best high-speed tools.
- c The thickness of the shaving; or the thickness of the spiral strip or band of metal which is to be removed by the tool, measured while the metal retains its original density; not the thickness of the actual shaving, the metal of which has become partly disintegrated.
  Proportion is as 1 with thickness of shaving $^3/_{16}$ of an inch to $3^1/_2$ with thickness of shaving $^1/_{64}$ of an inch.
- d The shape or contour of the cutting edge of the tool, chiefly because of the effect which it has upon the thickness of the shaving.
  Proportion is as 1 in a thread tool to 6 in a broad-nosed cutting tool.
- e Whether a copious stream of water or other cooling medium is used on the tool.
  Proportion is as 1 for tool running dry to 1.41 for tool cooled by a copious stream of water.
- f The depth of the cut; or one-half of the amount by which the forging or casting is being reduced in diameter in turning.
  Proportion is as 1 with $^1/_2$-in. depth of cut to 1.36 with $^1/_8$-in. depth of cut.
- g The duration of the cut; i.e., the time which a tool must last under pressure of the shaving without being reground.
  Proportion is as 1 when tool is to be ground every $1^1/_2$ hours to 1.207 when tool is to be ground every 20 minutes.
- h The lip and clearance angles of the tool.
  Proportion is as 1 with lip angle of 68 deg. to 1.023 with lip angle of 61 deg.
- i The elasticity of the work and of the tool on account of producing chatter.
  Proportion is as 1 with tool chattering to 1.15 with tool running smoothly.
- j A brief recapitulation of these elements is as follows:
  1 Quality of metal to be cut: 1 to 100;

[1] Prepared by Clarence A. Beckett, Secretary of the A.S.M.E. Special Research Committee on the Cutting and Forming of Metals.

Presented at the Machine-Shop Practice Session of the Annual Meeting of The American Society of Mechanical Engineers, New York, December 3 to 6, 1923.

[1] On the Art of Cutting Metals, Frederick W. Taylor, Trans. A.S.M.E. vol. 28 (1907), pp. 101, 102.

2 Chemical composition of tool steel: 1 to 7;
3 Thickness of shaving: 1 to $3^{1}/_{2}$;
4 Shape of contour of cutting edge: 1 to 6;
5 Copious stream of water on the tool: 1 to 1.41;
6 Depth of cut: 1 with $^{1}/_{2}$-in. depth to 1.36 with $^{1}/_{8}$-in. depth of cut;
7 Duration of cut: 1 with $1^{1}/_{2}$-hour to 1.20 with 20-minute cut;
8 Lip and clearance angles; 1 with lip angle 68 deg. to 1.023 with lip angle of 61 deg.;
9 Elasticity of the work and of the tool: 1 with tool chattering to 1.15 with tool running smoothly.[1]

Designs of Tools Used by Different Experimenters

9 Taking these elements as a base and knowing that more might be added, it is well to consider what sizes and shapes the different experimenters have used or developed.

10 *Taylor Tools Used on Trials.* Size varied, feed and speed varied, lip angles as follows:

Chilled iron or semi-hardened steel, 86 to 90 deg.
Tire steel (back slope, 5 deg., side slope, 9 deg.), 74 deg.
Mild steel, 61 deg.

11 The following are the conclusions arrived at regarding the angles at which tools should be ground:

a For standard tools to be used in a machine shop for cutting metals of average quality: Tools for cutting cast iron and the harder steels, beginning with a low limit of hardness, of about carbon 0.45 per cent, say, with 100,000 lb. tensile strength and 18 per cent stretch, should be ground with a clearance angle of 6 deg., back slope 8 deg., and side slope 14 deg., giving a lip angle of 68 deg. These angles are used in the tools illustrated on Folder 5, Figs. 21a and 25e.

b For cutting steels softer than, say, carbon 0.45 per cent having about 100,000 lb. tensile strength and 18 per cent stretch, tools should be ground with a clearance angle of 6 deg., back slope of 8 deg., side slope of 22 deg., giving a lip angle of 61 deg. These angles are used in tools illustrated in Folder 5, Fig. 25b.

c For shops in which chilled iron is cut a lip angle of from 86 deg. to 90 deg. should be used.

d In shops where work is mainly upon steel as hard or harder than tire steel, tools should be ground with a clearance angle of 6 deg., back slope 5 deg., side slope 9 deg., giving a lip angle of 74 deg.

e In shops working mainly upon extremely soft steels, say, carbon 0.10 per cent to 0.15 per cent, it is probably economical to use tools with lip angles keener than 61 deg.

f The most important consideration in choosing the lip angle is to make it sufficiently blunt to avoid the danger of crumbling or spalling at the cutting edge.

g Tools ground with a lip angle of about 54 deg. cut softer qualities of steel, and also cast iron, with the least pressure of the chip upon the tool. The pressure upon the tool, however, is not the most important consideration in selecting the lip angle.

h In choosing between side slope and back slope in order to grind a sufficiently acute lip angle, the following considerations, given in the order of their importance, call for a steep side slope and are opposed to a steep back slope:

1 With side slope the tool can be ground many more times without weakening it;
2 The chip runs off sideways and does not strike the tool posts or clamps.
3 The pressure of the chip tends to deflect the tool to one side, and a steep side slope tends to correct this by bringing the resultant line of pressure within the base of the tool.
4 Easier to feed.
5 The following consideration calls for at least a certain amount of back slope: An absence of back slope tends to push the tool and the work apart, and therefore to cause a slightly irregular finish and a slight variation in the size of the work.[2]

12 *Breckenridge and Dirks' Tests of High-Speed Tool Steel.* The shape of the tools used in these trials conformed to those recommended by Prof. J. T. Nicolson, who says: "Tools should therefore be ground for maximum endurance in the cutting of cast iron in ordinary shop practice so that their true cutting angles are about 81 deg.; or if they are allowed 6 deg. clearance for working on the level of the lathe centers, they should have an included angle of 75 deg."

13 Therefore the tools selected were:

Sizes: $^{1}/_{2}$ in. by 1 in., $^{3}/_{4}$ in. by $1^{3}/_{4}$ in., $^{3}/_{4}$ in. by $1^{1}/_{4}$ in.
Front clearance angle, $12^{1}/_{2}$ deg.
Top rake, 10 deg.
Side rake, 10 deg.

14 *French and Strauss, Bureau of Standards Trials.* In the experiments conducted at the Bureau of Standards by French and Strauss the size of the tools used was $^{1}/_{2}$ in. by 1 in.

15 Conditions of Test:

	Tests Run		
	1	2	3
Desired cutting speed, (ft. per min. at bottom of cut)	67	61	6
Feed, inches per revolution	0.045	0.045	0.045
Depth of cut, inches	$^{3}/_{16}$	$^{3}/_{16}$	$^{3}/_{16}$
Tool angles (degrees):			
Clearance	6	6	6
Back slope	$7^{1}/_{2}$	8	8
Side slope	12	14	14
Nose radius, inches	$^{3}/_{16}$	$^{3}/_{16}$	$^{3}/_{16}$

16 *Manchester Association of Engineers, Trials.* The tools used in the trials run by the association's Lathe Tools Research Committee were $1^{1}/_{4}$ in. by $1^{1}/_{4}$ in. The following is a summary of the first (16) trials.

Desired cutting speed, ft. per min. at bottom of cut	92.2 to 106
Feed, inches per revolution	0.0625
Depth of cut, inches	$^{3}/_{16}$
Tool angles (degrees):	
Clearance	6
Back slope	$14^{1}/_{2}$
Side slope	$14^{1}/_{2}$
Nose radius, inches	$^{1}/_{2}$

17 The second trials were conducted in the same manner as those mentioned above except that the cutting speed in feet per minute was increased to 115.3. Eighteen subsequent trials were run with the following changes:

Feed and depth of cut: $^{3}/_{8}$ in. deep by $^{1}/_{2}$ in. traverse; 3 in. deep by $^{1}/_{16}$-in. traverse; $^{15}/_{128}$ in. deep by $^{1}/_{10}$ in. traverse
Nose radius, $^{1}/_{4}$ in.
Tools having plan angles of 30 deg., 45 deg., 60 deg., 65 deg. and 90 deg.

18 *French, Strauss, and Digges, Tests.* The tools used in these tests were $^{1}/_{4}$ in. by $^{1}/_{2}$ in.

Desired cutting speed, ft. per min. at bottom of cut	70
Feed, inches per revolution	0.028
Depth of cut, inches	$^{3}/_{16}$
Tool angles (degrees):	
Clearance	6
Back slope	8
Side slope	14
Nose radius, inches	$^{1}/_{8}$

Size and Proportion of the Body of the Tool

19 Twenty-five years ago it was perhaps the more general custom in this country to make the cross-section of the body of lathe and planer tools square, and this practice still generally prevails in England and upon the Continent. In fact, in the report of the Manchester experiments, in which the tools of eight of the leading engineering establishments were placed in competition, all of the tools illustrated have square shanks.

20 It may be said, however, that the more general practice in this country at the present time is to make the depth of the body of the tool considerably greater than its width.

21 In choosing the proportion of the height of the shank to its depth, the effect of two forces must be considered: the downward pressure upon the nose of the tool, due to cutting the chip; and the side pressure at right angles to the tool, due partly to the feeding resistance and partly to the direction in which the chip moves across the lip surface.

22 Dr. Nicolson, in his experiments, has shown that in the great majority of cases the side pressure upon the tool does not exceed 20 per cent of the downward pressure; and that more frequently the side pressure is even a smaller percentage of the vertical pressure. On the other hand, tools when properly designed and properly placed in the tool post are supported in the majority of cases almost directly beneath the cutting edge, thus directly resisting the downward pressure upon the tool, and placing it mainly under compression, and so greatly diminishing the heavy downward transverse bending and breaking strains. If, then, tools were always set in their most advantageous position in the tool post, the practice of using steel of square cross-section might not be far wrong. However, in both lathe and planer work it is often necessary to set the tool with considerable overhang beyond the tool support, and in these instances it is evident that the depth of the tool should be considerably in excess of the width; because it must be borne in mind that the transverse strength of a rectangular bar under vertical pressure increases with the square of its depth, while it increases only in direct proportion to the width.

[1] On the Art of Cutting Metals, Trans. A.S.M.E., vol. 28 (1907), pp. 103, 104.
[2] Ibid., pp. 115, 116.

TABLE 1 COMPOSITIONS OF MODERN HIGH-SPEED TOOL STEELS[1]

Type of Steel	Brand	Results of chemical analyses, per cent: C	Mn	P	S	Si	Cr	W	V	Co	Mo	Ur
Low tungsten-high vanadium	A	0.64	0.43	0.019	0.025	0.15	3.43	12.72	1.85	....	....	....
		.74	.31	.008	.055	.51	3.56	13.05	1.73	....	....	....
	B	.60	.31	.023	.026	.34	4.29	13.32	2.15	....	....	....
		.73	.49	.012	.028	.37	3.30	13.36	1.71	....	....	....
Medium tungsten	E	.71	.23	.032	.027	.24	4.67	14.31	1.75	....	....	....
		.62	.14	.046	.040	.20	3.50	15.50	1.63	....	....	....
	D	.66	.23	.035	.018	.43	4.54	14.08	2.07	....	....	....
High tungsten-low vanadium	F	.69	.32	.001	.033	.18	3.80	18.00	.87	....	....	....
	X	.67	.19	.008	.057	.37	3.33	17.72	1.06	....	....	....
	Y	.63	.20	.009	.027	.21	3.05	18.71	.87	....	....	....
Cobalt	Q	.76	.34	.008	.061	.27	3.41	14.21	1.52	4.73	....	....
	R	.66	.20	.022	.019	.45	3.48	17.80	1.06	2.54	....	....
	S	.58	.09	.016	.026	.18	2.78	17.56	.93	3.35	....	....
		.72	.08	.020	.017	.11	3.26	18.40	.86	3.10	....	....
		.55	.42	.004	.063	.14	3.10	17.48	.75	3.78	....	....
Special steels:												
Uranium added	V	.66	.18	.035	.027	.39	3.94	13.80	1.45	....	....	0.23
	W	.64	.26	.027	.027	.17	3.21	17.03	.86	....	....	.26
Cobalt-molybdenum added	Z	.65	.28	.028	.045	.28	4.25	17.70	1.00	4.88	1.07	....
Tungstenless	CC	.65	.55	.027	.044	.48	4.62	.....	.68	4.73	4.72	Ni, 1.0 Cu, .12

[1] Technologic Paper No. 228 of the Bureau of Standards, French and Strauss, p. 221.

23 It is manifestly of great importance to have the tools as light as possible consistent with their strength both for ease of handling, in setting the tool in and removing it from its tool post, in grinding and in dressing; and a much lighter tool of equal strength and stiffness can be used when the height exceeds the width than when the cross-section is square.

24 For the above reasons some of the large machine shops in this country have adopted a proportion of 2 in height to 1 in width for the cross-section of their standard tools.

25 However, owing to the desirability of turning the noses of tools high above the top surface of the body of the tool for economy in grinding and dressing, and also owing to the design of the tool posts of the greater part of the machines in this country, it is, in the judgment of the writer, unwise to adopt a height as great as 2 to 1 for the body of the tool. After practical trial on a large scale and close observation of several different proportions, we have adopted as standard the section of $1^1/_2$ in height to 1 in width for the body of the tool.

26 There is one other element, however, which requires consideration, namely, the tendency to upset the tool or turn it over on to its side. It is clear that the higher the nose of the tool is raised above the point of support and the narrower the width of the tool, the greater becomes the tendency to upset the tool sideways; and that in many respects what may be called the English, Continental and old American standards of square-section tools with cutting edges close to the level of the top of the tool, appear to offer far greater stability than our standard.[1]

27 Now, considering the tables previously mentioned, it is evident that the design of cutting tools has changed very little even in the last twenty years, and that the tools recommended by Taylor are accepted as standard.

PROGRESS MADE TO DATE IN THE ART OF CUTTING METALS

28 However, one change has taken place and that is the chemical composition of the material used in the cutting tool. The tables given by Mathews on modern high-speed steel—Am. Soc. Testing Materials—and his summary cover the subject very well from our viewpoint.

Material Composing the Cutting Tool

29 Obviously the change from the old type of air-hardening steels to the modern type of high-speed steels is associated with the announcement of the Taylor-White process; that is, the high heat treatment given those grades as compared with the ordinary treatment of carbon tool steels.

30 *Summary.* The high carbon content and low tungsten or molybdenum content in Table 2 indicates the character of air-hardening steels in use prior to 1901.

31 In Table 3, although these analyses were made only one year later, it is seen that a change in character has come about, and relatively low carbon, with high tungsten or molybdenum is the characteristic feature of the new steels.

32 In comparing the analyses given in Table 4, which were selected as representative of a large number of domestic and foreign brands, it will be found that those steels cover quite a range as regards their chromium, tungsten, and vanadium contents. Steel No. 31 represents a type which was fairly generally used about ten years ago, in fact, various writers, as the results of practical tests, have contended that tungsten above 13 or 14 per cent is of no advantage.

33 Steel No. 34 is introduced because it corresponds quite closely with the analysis of steel to which Mr. Taylor referred as

[1] On the Art of Cutting Metals, Trans. A.S.M.E., vol. 28, p. 130, 131.

TABLE 2 SELF-HARDENING STEELS—1901

Maker No.	C	Mn	Cr	W	Mo
1	2.19	1.32	0.50	5.63	....
2	1.69	0.45	3.73	7.63	....
3	1.14	0.33	2.09	7.98	....
4	1.79	0.50	3.96	....	4.54
5	1.55	0.24	3.22	7.80	....
6	1.55	0.24	3.67	9.42	1.10
7	1.78	1.18	....	7.22	....
8	1.40	1.65	3.69	....	4.59
9	1.75	3.92	....	6.61	....

TABLE 3 HIGH-SPEED STEELS—1902

Maker No.	C	Mn	Cr	W	Mo
21	0.63	....	4.00	.....	6.00
22	0.42	....	4.95	10.75	....
23	0.57	0.43	3.30	11.58	....
24	0.75	....	....	19.50	....
25	0.37	....	5.10	13.83	....
26	0.62	....	6.50	21.06	....
27	0.84	0.07	2.76	11.25	....
28	0.56	....	2.95	9.74	....
29	0.60	0.30	....	.....	9.25

TABLE 4 STEELS IN USE IN 1922

Maker No.	C	Si	Mn	Cr	W	V
31	0.63	0.19	0.26	4.21	13.10	0.25
32	0.61	0.19	0.36	3.34	16.28	0.40
33	0.63	0.27	0.31	2.99	16.87	0.85
34	0.64	0.22	0.24	5.35	18.99	0.15

giving the best results obtained with any steel at the time he was actively engaged in this work.

34 Steel No. 32 is intermediate in quality as compared with Nos. 31 and 33. As a result of a very exhaustive series of cutting tests made as nearly as possible in accordance with the methods outlined and recommended by Mr. Taylor, these four steels will rank about as follows: Starting with No. 33 as 100 per cent efficient, Steel No. 34 would be represented by 70 per cent, No. 32 by 66 per cent, and No. 31 by 45 per cent.

Material Used in Testing Cutting Tools

35 One of the important factors entering into experimental work with cutting tools is the chemical composition and physical properties of the material to be cut. On this point there is a wide diversity of opinion among experimenters.

36 In the early trials of Taylor and Nicolson and those at Berlin a wide variation in the choice of metals is apparent, for mild steel, medium steel, hard steel, soft cast iron, and chilled cast iron were all experimented with. Later we find an experimenter who recommends the use of chilled cast iron or hard steel as a material to be used in testing cutting tools, because of the fact that the tool will "fall down" quicker, and thereby the expenditure of both material and time be lessened.

37 We can condemn this method on the facts already established and known, that a tool which will perform in a very satisfactory manner on mild steel will not be at all suitable for hard steel, and vice versa.

38 Two of the late experimenters, French and Strauss, chose a comparatively low-nickel steel for their lathe breakdown tests, while Schwartz and Flagle in their trials on tool temperatures used malleable iron, stove iron, gray iron, Armco iron, cold-rolled steel, and cast steel. In the latter experiments curves were plotted showing the average relation between temperature, rate of removal of metal, and energy input for the materials mentioned.

39 This subject of tool temperature is one about which very

little has been established. In their paper, mentioned above, Schwartz and Flagle, state it as their belief that the life of a given tool is a function of its working temperature, and hence that the temperatures reached under given cutting conditions in varying materials are an indication of their machinability or cutting hardness; however, in these trials a lubricant or coolant was not used.

40 The effect upon the cutting speed and also upon the cutting edge of a tool is a subject open to wide discussion. Taylor states that a heavy stream of water (3 gal. per min. for a 2-in. by $2^1/_2$-in. tool) will increase the cutting speed about 40 per cent.

41 The Manchester Committee in their trials on this subject used tools with $^1/_4$ in. nose radius and 6 deg. clearance angle, the cuts selected being $^3/_8$ in. deep by $^1/_{32}$ in. traverse and $^{15}/_{128}$ in. deep by $^1/_{10}$ in. traverse. The results show that with a cooling medium the appropriate cutting speed is increased by about 20 ft. per min.; also, as far as the results go, the cooling medium does not appear to affect the angle of greatest durability.

42 Both of the above experimenters are concerned only with water as a coolant, and it is therefore of interest to note Kingsbury's observations.

Lubrication and Cooling

43 *Kingsbury's Observations.* About 1895 Prof. Albert Kingsbury took the trouble to observe through a microscope the formation of a chip by the parting tool in a lathe, using mild steel. In this manner an important discovery was made. He found that a crack always preceded the point of the cutting tool. This crack develops in the direction of the circumference of the finished work below the tool. It forms the actual surface of the final work except when the tool is very dull, in which case this surface is rubbed or burnished by the tool itself. This circumferential crack which goes in advance of the cutting edge develops in a straight line for a certain distance and then turns off at 45 deg. with the original direction, branching out toward the surface of the chip, thus permitting the chip to unwind from the stock and slide out along the top of the tool. Immediately afterward a new crack is developed again in the circumferential direction, forming the next segment of the finished surface of the cut. These segments are recognizable in the ordinary cross-banded finish of the work as left by the cutting-off tool. The better the lubrication, the narrower are these bands.

44 Therefore Professor Kingsbury further observed just how the lubricant found its way between the chip and the top of the tool. It is sucked into the crack above the tool by the partial vacuum created when the crack first opens; the lubricant then adhering to the under side of the chip serves to lubricate the passage of the chip over the top of the tool. It is at just this point, namely, on the top of the tool, that the greatest friction of the chip takes place, and the lubricant must have such properties that it will reach this surface.

45 With a very viscous lubricant, or with a wide cut or with a high speed the lubricant does not find its way in quickly enough, and under such conditions it is familiar practice to use some very thin lubricant such as soda water or thin emulsion or other non-viscous cutting fluids.

46 *Proposed Experiments.* It might be of interest to subject Professor Kingsbury's conclusions to a quantitative test as well as to carry out more complete photographic or moving-picture observations of chip formation and lubricant flow under the microscope. For the capillary flow of lubricants having a constant viscosity, we should expect to realize the same degree of lubrication (evidenced possibly by the same degree of finish in the cut) when a cut three times as wide as another is produced by turning the work at one-third the speed of the other, and so on. More generally, should we not expect to find an equivalent result whenever the product of the viscosity by the width of the cut by the speed of the work has the same numerical value? Proper allowance for change of viscosity due to temperature and pressure presents a difficult problem of course, and directs attention to another line of possible experiments.

47 A second group of desirable experiments would consist evidently in actual determinations of the temperature and pressure at the point of a cutting tool. It is specially desirable that these conditions should be determined under the chip on top of the tool. The pressures at this point are probably of the order of 100,000 lb. per sq. in. when cutting steel and the temperatures may be several hundred degrees centigrade. The possibility of measuring these temperatures by employing the tool and the work material as parts of a thermocouple circuit was suggested by Dr. L. J. Briggs of the Bureau of Standards. Successful qualitative results (not yet reduced to exact numerical values) were obtained in this way by Mr. E. W. Butzler of the Physical Laboratory of the Bureau of Mines about six months ago. At this point Mr. Henry Shore, of the present senior class at the Massachusetts Institute of Technology, took an interest in the problem and hopes to have opportunity to work on it during the next few months, and in fact has already made a beginning. Mr. Shore further suggested that by the use of two thermocouple circuits, that is, by the use of two alloyed tools of different compositions cutting the same work material, it should be possible to eliminate the uncertainty due to the effect of pressure on thermoelectric power which would otherwise complicate the use of this method as originally suggested. It has been shown by Prof. P. W. Bridgman, of Harvard, that the thermal e.m.f. generated by different pairs of metals and alloys depends on the pressure as well as on the temperature. A further consideration of Mr. Shore's two-circuit method for temperature determination shows that it might be possible in this way to determine both the pressure and temperature at the point of the cutting tool. This method has many difficulties and is based on the assumption that the pressure and temperature are substantially the same for the same work material being cut under similar conditions by two different tools of different alloy composition. It consists in plotting for each tool a diagram with pressure and temperature as coördinates. On this diagram there will be a curve for each constant value of the e.m.f. generated. Now using tool No. 1 on the work we observe a certain e.m.f., say, 55 millivolts. This shows that the temperature at the point of the tool, and also the pressure, are represented by some point on the 55-millivolt curve of the diagram. Next using tool No. 2 we observe, let us say, 80 millivolts. The true temperature and pressure of the work is therefore represented by some point on the 80-millivolt curve for tool No. 2 and at the same time by some point on the 55-millivolt curve for tool No. 1. Therefore the true temperature and pressure must be the coördinates of the intersection point of those two curves when superposed. To prepare the necessary curve sheets, special experiments must be made to establish the thermoelectric power of the various combinations of tool and work material over the complete range of pressure and temperature desired.

48 Among recent attempts to measure the temperature at the point of a cutting tool, may be mentioned those described by H. H. Schwartz and W. W. Flagle in a paper entitled Significance of Tool Temperatures, presented at the Atlantic City meeting of the American Society for Testing Materials last June (address the Secretary at 1315 Spruce Street, Philadelphia, Pa.). The temperature near the cutting surface on drills was observed by means of thermocouples brought into the interior of the drill with the junction located near the cutting surface.

49 The recent experiments carried out for the special research committee on lubrication have a bearing on the problem of cutting-tool lubrication. These experiments serve to give us the viscosities of lubricants at different pressures and temperatures and have been carried thus far up to 50,000 lb. per sq. in. and will be continued. Lard oil remains exceedingly fluid at higher pressures than any other thus far tested, and this fact may be in agreement with common experience regarding the superiority of lard oil for cutting steel at moderate or low speeds. Most oils become exceedingly viscous or else suddenly plastic at certain critical pressures. For example, whereas lard oil at 100 deg. cent. remains fluid well beyond 3000 kg. per sq. cm. (1 kg. per sq. cm. = 14.2 lb. per sq. in.), on the contrary castor oil at the same temperature becomes plastic or solid at 2900 kg. per sq. cm. It may be that these oils which become plastic or solid at low pressures are unsuitable for cutting tools and that the viscosity experiments may give us a clue to fluids having desirable properties as cutting-tool lubricants.

50 The suggestion ventured above to the effect that lard oil may owe its lubricating value to its ability to resist solidification under pressure is to be regarded only as an individual speculation. Much further work should be done to determine what degree of correlation there is, if any, between the viscous or plastic properties

of lubricants under pressure on the one hand, and their suitability as cutting-tool lubricants on the other hand. The above suggestion pictures the mechanism of lubrication under the chip as follows:

51 When a mineral oil adhering to the lower surface of the chip is dragged into the place where pressure begins to develop, it solidifies and creates excessive friction. The lard oil, on the contrary, may possess just the right viscosity under pressure to serve effectively as a lubricant. It is evident that an oil would fail to give satisfactory lubrication under the chip, after having reached that spot, if the resulting combination of pressure and temperature should make it either excessively viscous (or plastic), or excessively fluid.

52 To secure actual knowledge on this matter will require two lines of research; first, the measurement of viscosity of all lubricants under extreme pressures and temperatures; and second, determination of the actual temperatures and pressures existing under the chip of the cutting operation. There are other properties of liquids such as adhesion and adsorption which doubtless enter the phenomena and which eventually should be investigated under high pressure and high temperature.

53 *Adsorption.* The individual oils differ greatly from each other in regard to the force with which they adhere to the surfaces of other substances. If a small proportion of asphaltum or gummy oil forms one of the constituents of a lubricating oil, its tendency to concentrate to a minute extent in the surface of the oil makes it possible that some of the lubricating value and possibly some cooling effect may be destroyed.

RESEARCH PROBLEMS

54 It is evident that this question of lubrication and cooling should receive considerable attention due to its apparent value. However, the Committee feels that other factors are of greater importance at present and lists them below in the order of their relative value.

55 *a* The development of a standard method for testing tool material and material to be cut.

- *b* The development of a standard heat-treating method.
- *c* The development of standard tools.
- *d* The development of methods for testing tool performance.
- *e* The development of a method for testing cutting fluids (lubricants and cooling agents).
- *f* The formulation of a definite basis for specification of work material, tool material, and cutting fluids.
- *g* Experimental research to establish, gradually, the general and fundamental laws governing the relation between tool performance (in its several aspects) on the one hand, and the numerous independent variables on the other, such as the various factors of tool design and adjustment (form and rigidity of tool, side slope, back slope, clearance angles, etc.), speed of work, depth of cut, feed, nature of materials concerned (tool, work, and fluid), temperature, and methods of lubrication and cooling.

BIBLIOGRAPHY

56 The value of a bibliography on the art of cutting metal is well appreciated by the Committee. In fact, a start has been made toward compiling one. The value of such a list, however, will be increased as manufacturing firms and individuals who are doing experimental work send us their reports and the results of their tests.

SUGGESTED METHODS OF FINANCING THE RESEARCHES TO BE PLANNED BY THIS COMMITTEE

58 At the present time many of the machine-tool builders and users and perhaps all of the steel manufacturers are carrying on research to some extent. While these researches are intended primarily to serve the individual commercial interests of the firms in question, the Committee believes that much can be done to avoid duplication of work and its attendant delay and economic loss. By complete coöperation between the Committee and the industry projects will be undertaken by those best able to handle them and the results will be made available to all for the good of all.

59 In addition to the individual firms many organizations are already at work in this field. Notable among these are the American Society of Steel Treaters, the National Machine Tool Builders' Association, the National Research Council, the Bureau of Standards, organizations in foreign countries, and the technical schools and colleges of the United States.

60 All of these organizations will have from time to time funds in varying amounts which they intend to devote to studies in the different parts of this field. The Committee hopes to be able to so serve these organizations that these moneys will be wisely expended for the good of the greatest number. The A.S.S.T. secures funds for research from its contributing memberships. The members of the N.M.T.B.A. are more and more realizing the dollars-and-cents value of research to their industry. Through the Bureau of Standards certain limited Government funds become available for use on this subject, and in addition members of the regular staff make studies for the various Government departments. In the past many of our technical schools have been supplied with funds by individual firms or groups of firms for researches on specific parts of this subject. The Committee hopes to assist in this work by suggestion and by contributing data, and in turn to be permitted to disseminate the results.

61 It may reasonably be expected that a show of results accomplished by the Committee will in time bring about direct contributions to the A.S.M.E. from some of its generous friends for the support of this particular research work. In the absence of such needed funds it is submitted as the opinion of this Committee that the Society can foster, direct, and coördinate such work wherever done by coöperating with the societies, institutions, and firms doing research work. In this manner we may reduce duplication of effort and assure maximum results from such funds as are available. Where the necessary funds for any particular project recommended for research are lacking, the Society through a properly constituted committee might with propriety undertake the solicitation of contributions for that specific purpose.

SUMMARY OF RESEARCH WORK ON THE ART OF CUTTING METALS

62 We know too little about what actually happens at the cutting edge of a tool, that is, we do not have a complete law of the "speed," "feed" and "depth" of cuts. With respect to the hardening, rehardening, tempering, and annealing of high-speed cutting tools, it is a case of absence or confusion of specific laws regulating temperatures, time, and definite hardness. Again, the chemical analysis and physical properties of both the cutting tool and the material to be cut have received insufficient consideration, and also the theory of chip formation is not sufficiently established.

63 It is not the purpose of this Committee to criticize in any way the valuable research work which has been done in the art of cutting metals, but rather to correlate the most reliable data and to review the research that has been made by manufacturing firms of the industry and the technical departments of the universities and colleges, and to make note of those factors upon which no research has been attempted or upon which reliable data are not available.

Historical Review

64 The history of tool steels may be traced back for years. It is said that the ancient and celebrated Damacus steel was a form of tungsten alloy, but so far as modern development is concerned, it was not until 1860 that Robert Mushet discovered that the addition of manganese and tungsten to carbon tool steel, gave to tools made from it a cutting edge that would withstand much higher temperatures, and consequently permit higher cutting speed to be employed.

65 It was with this air- or self-hardening steel as a base that Taylor and White undertook their long series of experiments on and discovered the latent possibilities of tungsten as an alloy. They found that although the steel was apparently injured at comparatively low temperatures, upon heating up to 2000 deg. fahr. or even up to the "burning" point, the efficiency was greatly increased from 30 ft. per min. to 80 or 90 ft. per min.

66 As the result of these experiments[1] tests were conducted all over the world with very conflicting results in consequence. The Berlin section of the Verein Deutscher Ingenieure conducted an extensive series of experiment to determine:

- *a* The maximum surface that could be machined in unit time with a given cut of $^3/_{16}$ in.; the traverse and speed being at the option of the experimenters.
- *b* The weight of cutting that could be removed per unit of time with the greatest possible depth of cut, the traverse feed and speed being again left open.

67 The materials used in this test were gray cast iron, cast steel, and

[1] See Lathe Design for High- and Low-Speed Steels, by Nicolson and Smith, now out of print.

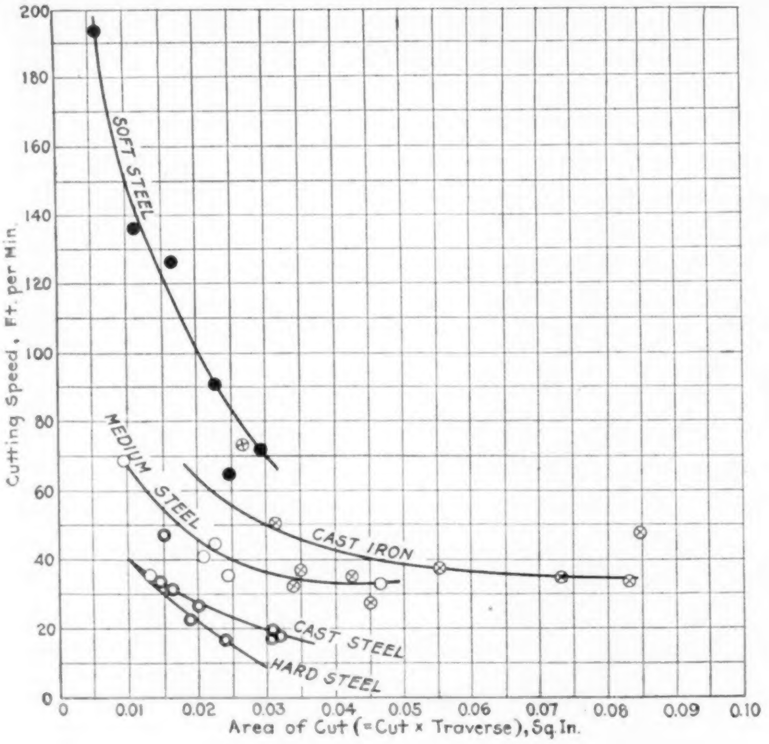


Fig. 1 Berlin Tool-Steel Tests

forged or rolled Siemens-Martin steels of different physical characteristics. About two hundred and fifty trials of duration up to two hours each were made and a selection of the best results is represented in Fig. 1 where fair curves are drawn through the points obtained for each material.

68 The curves give the relation between the cutting speeds and the areas of cuts for which the tools endured at least one hour—with one or two exceptions—without regrinding. The curve marked "soft steel" is for cuts taken upon Siemens-Martin steel of 26 tons tenacity; while the "medium steel" and "hard steel" curves were for the same material, but with ultimate strengths of $40^1/_4$ and 49 tons, respectively.

69 Practically one year later a series of experiments extending over a period of ten months were conducted at the Manchester Municipal School of Technology, their object being to establish

a The maximum cutting speed that can be obtained with the new steels when taking light or finishing cuts upon hard, medium, and soft steel, and upon hard, medium, and soft cast iron.

TABLE 5 MANCHESTER EXPERIMENTS

Intended cut and traverse for all tools, in.		Actual area of cut, sq. in.: Non-failing tools of greatest speed	Actual area of cut, sq. in.: Average of all non-failing tools	Cutting speed, ft. per min.: Greatest speed of any non-failing tool	Cutting speed, ft. per min.: Average speed of all non-failing tools	Weight removed, lb. per min.: Greatest weight removed by any non-failing tool	Weight removed, lb. per min.: Average weight removed by all non-failing tools	Force and stress: Average cutting force of all non-failing tools	Force and stress: Average cutting stress of all non-failing tools, tons per sq. in.
Soft Steel (Whitworth Fluid-pressed)									
1/16	1/16	0.0032	0.0035	149.2	125.9	1.72	1.455	921	117
3/16	1/16	0.0106	0.0104	111.0	95.8	4.14	3.42	2,590	111
3/16	1/8	0.0215	0.0210	74.0	62.8	5.28	4.38	5,454	115
3/8	1/8	0.0434	0.0422	50.7	44.5	7.5	6.26	11,740	124
Medium Steel (Whitworth Fluid-pressed)									
1/16	1/16	0.0039	0.0036	105.2	101.7	1.5	1.295	925	115
3/16	1/16	0.0114	0.0115	80.0	71.8	3.17	2.8	2,743	$106^1/_2$
3/16	1/8	0.0227	0.022	51.4	49.9	3.88	3.68	5,742	116
3/8	1/8	0.0425	0.0428	38.6	37.8	5.60	5.47	10,437	109
Hard Steel (Whitworth Fluid-pressed)									
1/16	1/16	0.0040	0.0037	52.5	51.3	0.73	0.66	1,274	154
3/16	1/16	0.0124	0.012	41.2	40.6	1.71	1.64	3,658	136
3/16	1/8	0.0219	0.0219	30.8	30.8	2.3	2.3	7,960	162
3/8	1/8	0.0452	0.0438	20.2	19.6	3.1	2.91	15,220	155
Soft Cast Iron									
1/16	1/16	0.0039	0.00397	109.0	105.25	1.3	1.27	489	55
3/16	1/16	0.0214	0.0123	99.5	85.26	3.6	3.1	1,051	38
3/16	1/8	0.0214	0.0210	66.2	65.1	4.38	3.97	2,555	54
3/8	1/8	0.0459	0.0456	55.5	50.75	7.46	7.02	4,403	43
Medium Cast Iron									
1/16	1/16	0.0033	0.0035	59.7	54.1	0.69	0.65	818	104
3/16	1/16	0.0115	0.0107	49.0	44.6	1.73	1.51	2,045	85
3/16	1/8	0.0227	0.0201	33.1	32.5	2.23	2.07	3,630	$80^1/_2$
3/8	1/8	0.0446	0.0443	24.3	23.2	3.32	3.13	6,035	61
Hard Cast Iron									
1/16	1/16	0.00375	0.0037	38.5	37.6	0.48	0.45	953	115
3/16	1/16	0.01173	0.011	31.9	29.7	1.18	1.04	2,009	81
3/16	1/8	0.02112	0.0204	24.7	22.74	1.62	1.39	3,772	83
3/8	1/8	0.0459	0.0342	22.0	19.0	3.2	2.56	5,443	56

b The maximum area of surface that can be machined in a given time when taking a $^3/_{16}$-in. cut with the new steels upon the six given materials.

c The greatest weight of cuttings that can be removed from these three grades of steel and of cast iron.

d The forces operative upon the tool in making these cuts and the law according to which these forces vary with the speed of cutting and the area and shape of cut.

e Whether these new steels can be forged and tempered by an ordinary smith and yet be relied upon to give results as to cutting speed and durability similar to those obtained when they are delivered ready ground by the makers.

70 Data in regard to the first four of these items are concisely given in Table 5 which has been abstracted from the results of the report. The table is self-explanatory, and it need only be added that "non-failing tools" are those which were capable of further cutting at the expiration of twenty minutes; and tools which failed were those whose withdrawal was necessary before the expiration of that time. In the last two columns are given the values of the cutting forces and the cutting stresses—or forces divided by areas—for each variety of cast iron, or steel irrespective of the size or shape of the cut taken; the assumption that the cutting force is proportional to the area of the cut being as a first approximation assumed to hold.

71 Figs. 2 and 3 give these results as originally in the report, and the curves plotted in them will be found to be generally in close agreement with the numerical results of Table 5. The speeds plotted on a base of area cut are those at which the tool must run for the corresponding cuts, if it is to last equally long in each case. The formulas found most closely to represent the relation between speed and aera were of the form

$$v = \frac{K}{a + L} + M$$

v being the cutting speed in feet per minute, a the area of the cut in square inches, and K, L, and M constants whose physical significance need not be further discussed at this point, but whose numerical values for the various materials operated upon are as follows:

Constant	Fluid Pressed Steel: Soft	Fluid Pressed Steel: Medium	Fluid Pressed Steel: Hard	Cast-Iron Bars: Soft	Cast-Iron Bars: Medium	Cast-Iron Bars: Hard
K	1.95	1.85	1.03	3.10	1.65	1.30
L	0.011	0.016	0.016	0.025	0.030	0.035
M	15.0	6.0	4.0	8.0	7.0	5.5

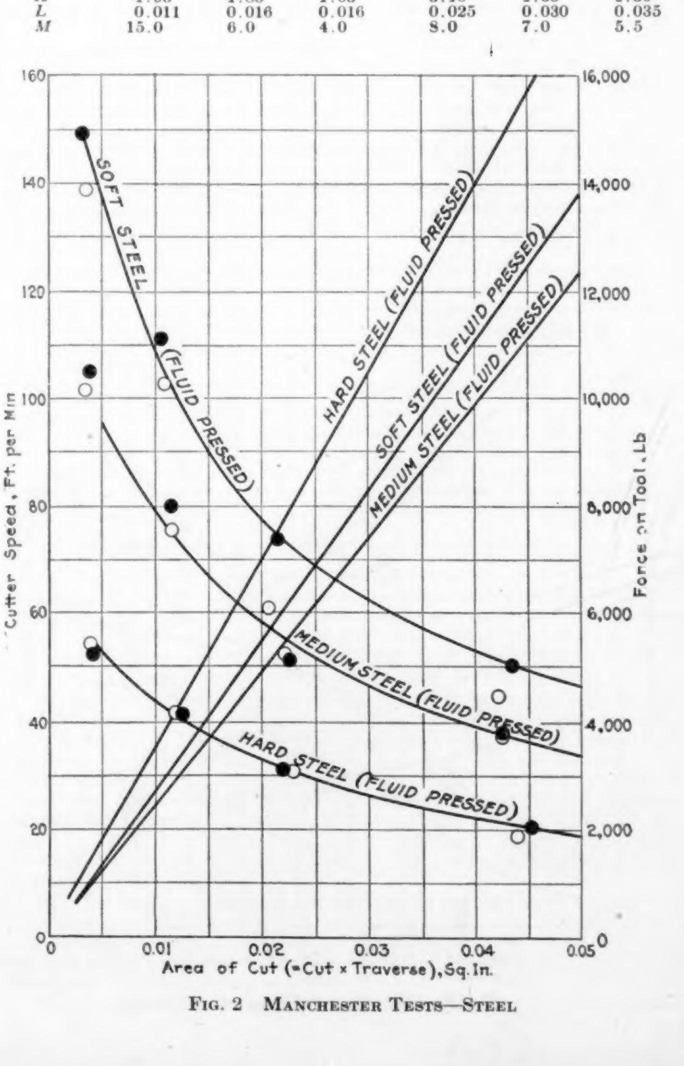


Fig. 2 Manchester Tests—Steel

72 In Fig. 4 the speed-on-area results from both the Berlin and Manchester trials have been plotted together (open dots, Berlin; full dots, Manchester). The thick black curve depicts the relation between cutting speed and area of cut given by the formula

$$v = \frac{1}{a} + 15 \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where v = cutting speed in feet per minute, and a = area of cut in square inches.

73 This is the formula for the speed at which a given cut is assumed to be taken under ordinary workshop conditions, and at which the heaviest cut for which a given lathe is designed must be taken, when under test.

74 It is seen to be well within the highest values obtained in the Manchester experiments, but passes close to those obtained in Berlin for the lightest cuts. This is justified by the consideration that the Berlin trials given speeds for which the tools lasted over one hour, while the Manchester results are for tools intended to last only twenty minutes. The so-called "soft steel" used in the Manchester trials was very tough, and it is therefore possible that the constant in Formula [1] may be taken as high as 25 for ordinary "machinery steel" without an undue amount of destruction of the tool being encountered in ordinary practice.

75 The round-dot curve traced on Fig. 4 shows the relation which would have obtained between speed and area had it been experimentally found that the speed of cutting could increase as fast as the area of the cut diminished, i.e., that the same weight could be machined off per minute for a light as for a heavy cut. We see at a glance that when the area is reduced from 0.1 sq. in. with a speed of 33 ft. per min. to 0.5 sq. in., e.g., the speed, instead of being increased 100 per cent can only be raised by 42 per cent; and that if reduced to 0.025 sq. in. the speed can only be about doubled instead of being increased fourfold. The weights removed will therefore be 3/4 and 1/2, respectively, in the two latter cases, of what could be removed when the cut was 0.1 and the speed 33. For light cuts, such as 1/16 in. by 1/16 in., of area 0.005, weight can be machined off which only amounts to 20 per cent of what can be removed with a cut of 1 in. by 0.1 in. traverse.

76 In Fig. 5 are shown curves which fairly represent the weights removed per minute in the committee's experiments and in subsequent trials. It is inserted here for convenient reference. The full lines are for steel; the dotted are for cast iron. The points give the actual results obtained, being the greatest weights removed by any non-failing tool on each of the four series of trials made with the six samples operated upon. As ordinates we have pounds removed per minute, as abscissas area of cut—or depth of cut by width of traverse. Since $W = MaV$, where M is the density of the material, a the area of cut, V the speed, and W the pounds removed per unit of time, we have $W/a = MV = \tan \alpha$. This means that if a

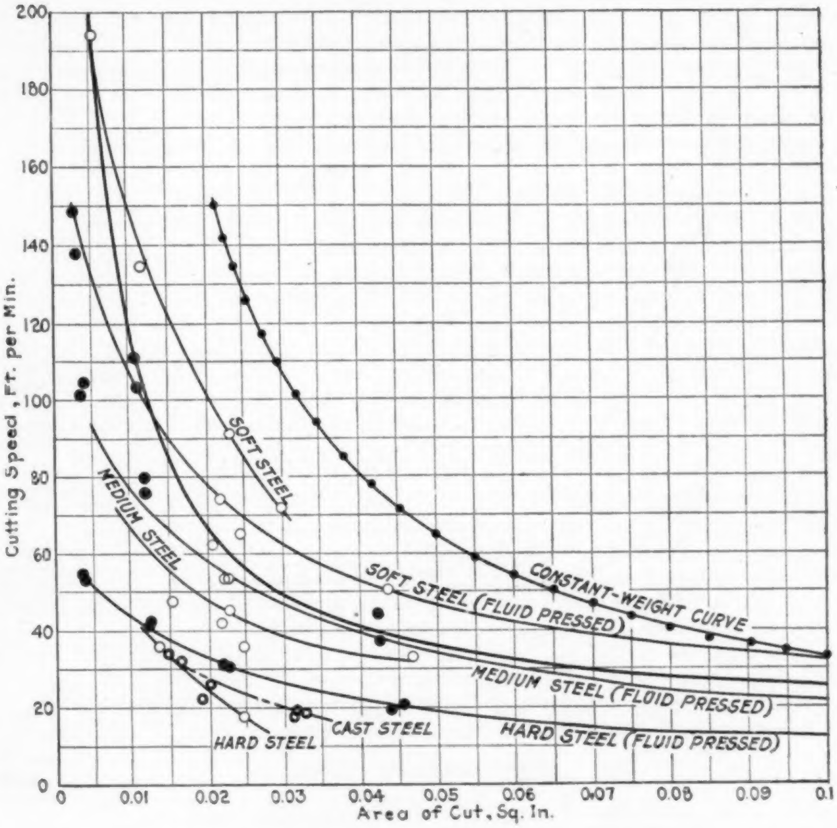


Fig. 4 Tool-Steel Tests—Berlin and Manchester

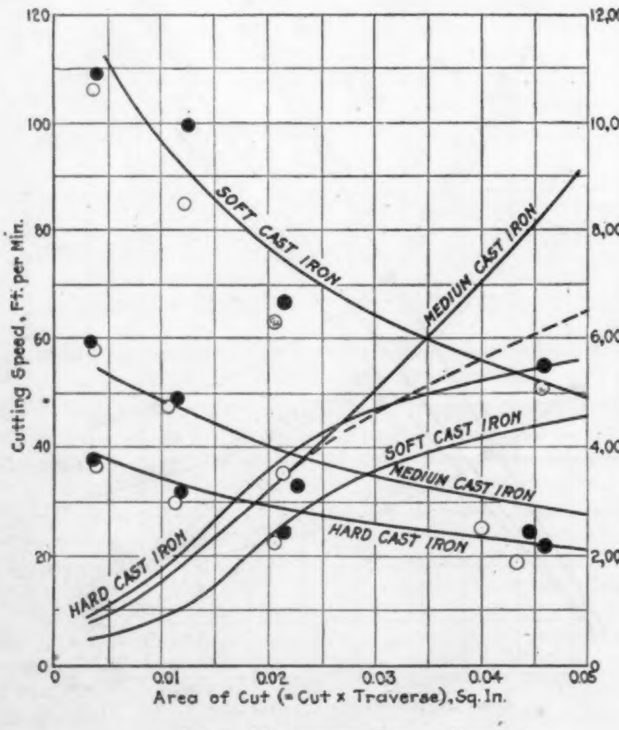


Fig. 3 Manchester Tests—Cast Iron

sloping line be drawn through the origin of coördinates of the diagram of weights and cuts, making with the axis of areas an angle α, whose tangent is MV, this sloping line will join points giving the weights removed for each cut at the given speed V — if this be a possible speed. Such sloping lines will, in fact, be (contour) lines of constant speed, and are a useful addition to the diagram of weights removed. Thus, e.g., if we wish to know at what speed 5 lb. per min. can be removed, we can tell at a glance by running across the diagram upon the 5-lb. line that the speed would have to be 200 ft. per min. for a 1/8-in by 1/16-in. cut (0.00391 area), 96 ft. per min. for a 1/8-in. by 1/8-in. cut (0.0156 area), and 33 ft. per min. for a 3/8-in. by 1/8-in. cut (0.047 area).

77 The first speed is impossible on materials operated on, the second is problematic, and the third could only be taken upon the milder varieties of steel. Or, conversely, we can tell the weights which will be removed if we run at a given speed on a given material; also the depth of cut and width of traverse we may safely employ at that speed.

The Manchester Experiments

78 Relative to these three series of experiments, the Manchester, Berlin, and Taylor, it should be noted that the first two were of comparatively short duration, while the Taylor results were obtained only after fourteen years of exhaustive research. We might quote Mr. Henry R. Towne: "Based on what is undoubtedly the longest, largest, and most exhaustive series of experiments ever conducted in this field, its summary of the conclusions deduced therefrom embodies the most important contribution to our knowledge of this subject which has ever been made." However, the results obtained by all three experimenters were far from being complete and the value of the data thus far accumulated could be questioned, due to the further development of high-speed steel.

79 It is not surprising, then, that the Manchester Association of Engineers should have undertaken a second investigation on the cutting capabilities of these improved steels.

80 This investigation was carried out under the supervision of Mr. Dempster Smith in association with the Lathe Tools Research Committee of the Manchester Association of Engineers.

81 The experiments conducted extended over a period of years (1919–1922) and was interrupted only for a short time during the war.

82 As the heat treatment of tools is one of the most important points to be considered, the committee decided that this part of the subject should receive first attention.

83 Accordingly their first object was to obtain a heat treatment of tool steel that would give consistent results. The procedure was as follows—To indicate whether

- *a* With the heat treatment adopted consistently uniform results were obtained.
- *b* The performance of the tool when reground after failure was better than in the first trial.
- *c* Subsequent heat treatment restored the tool to its original vitality.

83 A round-nosed tool was selected because of its extensive use in practice for roughing purposes and because of its reputed durability. The

shape chosen had a nose radius of $^1/_2$ in., a cutting angle of 70 deg. in a plane of 45 deg. to the length of the tool (approximate plane of the shaving) which is equivalent to a front and side top rake of $14^1/_2$ deg. and a clearance angle of 6 deg. The tools were $1^1/_4$ in. square in section. In the heat treating the tools were preheated for $7^1/_2$ min. in the low-temperature chamber of a two-stage furnace at 820 deg. cent. and immediately transferred to the high-temperature chamber at 1275 deg. cent. where they remained for $1^3/_4$ min. and afterward were quenched in molten metallic salts at 250 deg. cent.

84 The deductions may be summarized as follows:

a That with freshly forged tools, hardened as stated and tested under identical conditions, it is possible to obtain results within a difference of 9 per cent.

b That the cutting capacity of a tool which has been tested as stated is not appreciably impaired by being rehardened as often as three times, but care must be taken to insure that the whole of the previously injured part is removed in the grinding rehardening.

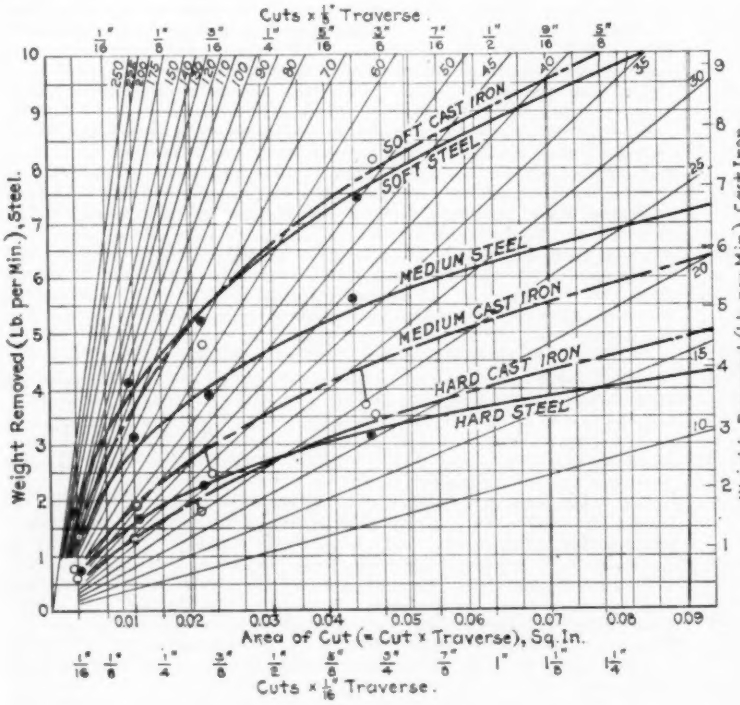


FIG. 5 WEIGHT OF METAL REMOVED

(Lines radiating from origin of coördinates are lines of constant speed in feet per minute.)

c That annealing prior to hardening has no appreciable effect on the cutting capacity.

d That the subsequent performance of a tool which has been simply reground (after being hardened and failed as stated) is not equal to the original.

85 In connection with the above investigation one observation is well worth bringing forth, namely, that in the high-temperature treatment there appeared to be four visible changes in the condition of the surface of the steel:

a The glowing stage at the cutting edge is preceded by bright glowing specks, about the size of a pin point, appearing round the extreme edge and merging into one another, producing a glowing strip.

b Almost simultaneously with the appearance of this strip bright specks (about $^1/_{16}$ in. diameter) appear immediately behind the former, and these travel backward across the face in a cluster about $^3/_{16}$ in. wide.

c The metal immediately behind this moving cluster of glowing specks seems for a time to be in a quiescent state.

d Ultimately the last-mentioned surface appears to rise like a bubble, generally bursting at the cutting edge.

86 The deductions from trials relative to the blistering of the tool nose are: That the steel was in its best condition at the part containing the glowing specks as blistering at the time of cooling, i.e., $^1/_4$ in. from the nose. This result was confirmed by other tools, the heat treatment of which had been prolonged to different degrees, and the conclusion arrived at was that portion of the tool in front of the glowing specks had been overheated, while the portion beyond had not been sufficiently heated.

87 In the resumption of their trials the following program of research was outlined.

a That two tools be forged and ground to the same shape and angles as those used in previous trials and hardened by heating to a temperature of 1320 deg. cent. and cooled in an air blast. Afterward these tools were to be heated in a muffle furnace at 500 deg. cent., maintained at this temperature for 10 min. and on withdrawal to be allowed to cool in still air. The cutting tests to be continued until the tool failed, and after each failure the tools were to be simply reground on the wet sandstone by hand ($^1/_8$ in. being ground off the front face each time) and tested again; this procedure being continued until the entire cutting face was used up.

b That in order to obtain a measure of the cutting performance of a "normalized" and an "annealed" tool, two tools be forged and ground to the standard shape, these to be subsequently heated to the forging temperature and one allowed to cool in still air on the floor, the other being buried in hot ashes.

c To continue to seek for a reliable method of heat treatment for lathe tools.

d To continue the inquiry for some simple and expeditiously applied test which should show whether the cutting portion of a tool is in an efficient condition and which could be applied before the tool is issued from the toolroom.

88 *Deductions from Results.* *a* The cutting performance in the first trials was remarkably regular throughout; however, an attempt to repeat these trials produced unsatisfactory results, which let the committee to modify their high-temperature furnace so that it would produce uniform results. The conclusions arrived at after subsequent trials brought out the fact that the cutting performance in the last trial with each tool is generally good. The comparatively poor results in some of the intermediate trials is attributed to insufficient material having been ground off the nose after previous failure. Scleroscope readings indicated that the bar was of uniform hardness throughout its length, and failures were not common at any particular part of the bar.

b The performance of tools treated at 1250 deg. cent. were poor compared with tools treated at 1325 deg. cent.

c The reheated tools gave a cutting performance slightly higher than those which had not been so treated.

89 The fourth item, "To obtain a single and expeditiously applied test which would show whether the cutting portion of a tool was in an efficient condition," was developed as follows: A glazier's diamond was mounted on an arm free to move vertically and capable of swiveling around a vertical pillar. A sleeve around the pillar carried a projection whereby the arm could be swiveled by hand without interfering in any way with the load on the arm. A weight of about 10 oz. was mounted on the end of the diamond holder and the best cutting edge of the diamond faced the direction of motion. A micrometer microscope, capable of measuring 0.001 mm., was used for measuring the width of the scratch. In addition to the scratch test, scleroscope readings were also taken.

90 It was observed that the width of the scratch varies inversely as the cutting performance of the tool, but from repeated experiments it seemed improbable that this test would afford a reliable measure of the cutting capabilities of a tool.

91 It was also observed that there is no close relationship between the scleroscope hardness figures and the cutting efficiency of the tool.

Hardness readings obtained from specimens which had been reheated to 600 deg. cent. after being heated to 450 deg. cent. and allowed to cool in still air compared favorably with those which had been heated direct to 600 deg. cent. and also with those which had been quenched out from 1325 deg. cent. The results show that if there is any cumulative effect due to successive heat treatments it must be very small. However, it was found that the hardness figures after reheating to 450 deg. cent. following a reheating at 600 deg cent. were identical with those specimens cooled directly from 600 deg. cent., and also with those quenched from temperatures between 1325 deg. cent. and 1400 deg. cent. It therefore appears that the second heating to 600 deg. cent. renders the steel more stable at all temperatures up to 600 deg. cent.

92 This result is important and if substantiated by other tests a partial explanation is forthcoming of the erratic behavior of some tools in the cutting trials. A tool which has been cooled from about 1320 deg. cent. and not subjected to a second heat treatment may be raised when cutting to a temperature of about 600 deg. cent., for some distance across the face. On regrinding the tool for a second trial, it is possible that the new cutting edge will be formed at that part of the tool which had been heated to about 600 deg. cent.

93 *Magnetic and Electrolytic Tests.* It was thought that use might be made of the different magnetic properties possessed by a piece of steel according to the heat treatment to which it had been subjected. Accordingly a ring of tool steel was forged, and its magnetization curves determined (*a*) when annealed, (*b*) when hardened, and (*c*) when hardened and tempered. These curves were sufficiently distinct one from another to warrant a further prosecution of investigation along these lines.

94 The experiments carried out were divided under the following two heads: tractive-force measurements and coercive-force measurements. The irregularity of the results obtained in both series of trials was such as to render them of no practical value.

95 The trials run in the investigation of the electrolytic method to determine what difference, if any, existed in the electromotive force set up between a specimen of heat-treated tool steel and a carbon rod, with the use of a suitable electrolyte, were very unsatisfactory, the readings on the voltmeter in successive experiments on any one specimen of tool steel differing considerably.

96 The results of trials on the variation in the durability of tools with change in the cutting speed, shape, cutting angle, nose radius, different cross-sections, different depths of cut and traverse, tools operating dry and with a cooling medium, and tools operating dry on different grades of steel, may be briefly stated as follows:

97 The types of tools selected were 30-, 60-, and 90-deg. round-nosed tools.

98 The trials were reduced to a "constant duration" and the appropriate cutting speed for a 20-min. life. It was observed that the cutting performance of all tools has a minimum value when the ratio of depth of cut to traverse is approximately unity, also that with the exception of the 60-deg. tool the relative difference in the cutting speed remains practically unchanged.

99 During the trial there appeared two distinct phenomena to be explained, viz.:

a Why the cutting performance of any one tool is a minimum where the ratio of depth of cut to traverse is unity, and improves for values greater or less than this.

b Why the performance of one tool is better than that of another on any one cut, and why the relative superiority of one tool over another is not maintained at all cuts.

100 When a tool is operating, the intensity of pressure is greatest at the nose while the cutting speed is greater at the outer extremity of the cut, and depending upon the relative effect of these two factors, the point of highest temperature will move toward one end or other of the cut, provided the heat is uniformly dissipated. The fact that discoloration on the tool surface is roughly equidistant from the cutting edge suggests that the dissipation of the heat into the tool is uniform. The heat dissipated into the tool is dependent upon the perimeter of the cut, and this results in an increasing rate of dissipation with increase of cutting edge engaged for a constant area of cut. Dissipation of heat also takes place by radiation from the shaving, and as the width of the latter increases, a greater surface is exposed to the cooling action of the air, and the rate of heat dissipation is correspondingly increased.

101 This permits of a partial explanation of the phenomenon (*a*) enumerated above.

102 With a decrease in traverse (constant area of cut) there is less crowding and consequently less heat produced. There is also an increase in the rate of heat dissipation into the tool and surrounding air, thus giving the tool a lower temperature and increased durability. A similar effect is produced where the ratio of traverse to depth of cut is large.

103 On the other hand, as the traverse decreases and depth of cut increases, the velocity at the outer edge of the tool becomes appreciably greater than the mean, and this would tend to cause the tool to fail at that part; but as the effect due to this increased velocity can be shown to be small in comparison with that due to heat dissipation, the cutting performance improves as the ratio of cut to traverse becomes greater or less than unity.

104 With regard to the phenomenon (*b*), it should be noted in making comparisons that the 90-deg. and 60-deg. tools had a $^1/_{16}$ in. nose radius, and that the 30-deg. and round-nose tools had a $^1/_4$ in. nose radius. Further, the 90-deg. tool had a side cutting angle of 70 deg., while the other tools had a side cutting angle of 75 deg. in each direction.

105 Comparing the 90-deg. tool with the others, the small radius at the nose and the large angle subtended by the latter would cause excessive crowding and heating, and this tool invariably failed at the nose. Again, the true cutting angle (i.e., the angle in the plane in which the shaving crosses the tool surface) in the 90-deg. tool varies from 80 deg. to 75 deg. as the depth of cut increases; whereas the corresponding true cutting angle for the other tools only varies from 71 deg. to 70 deg. for the same range of cuts, and on medium steel a 70-deg.-cutting-angle tool gives a slightly higher durability for most ratios of depth of cut to traverse. Further, the width of the cut is relatively small, and the rate of heat dissipation is correspondingly less. All these adversely affect the performance of this tool. Every consideration goes to show that when operating on a diameter of bar such as that used in these trials, the performance of this tool cannot be expected to equal that of the others.

106 Turning now to the round-nosed tool, the larger nose radius, as well as the smaller angle subtended by the same and the longer cutting edge engaged, are all in favor of a higher appropriate speed than is possible with a 90-deg. tool. The same remarks could be applied to the 30-deg. tool, and the small angle subtended by the nose radius, together with the increased length of cutting edge, gives this tool a durability considerably greater than that of the round-nosed tool.

107 When cutting with the 30-deg. tool, however, it was observed that as the traverse decreased below $^1/_{32}$ in., the vibration increased conspicuously. Owing to the decreased thickness of shaving relative to that of the other tools at the same traverse, the cutting edge is snipped off or dulled by the hammering action, and failure is thereby accelerated. This action accounts for this tool failing to maintain the relative superiority held on the coarser traverses.

108 The performance of the 60-deg. tool on the coarser traverses lies between that of the 90-deg. and round-nosed tools. Its position relative to the 90-deg. tool is attributed to a smaller angle subtended by the nose, a longer cutting edge, and a more favorable cutting angle, and its position relative to the round nose to the fact that the nose radius is smaller.

109 As the cut increases in depth and the traverse diminishes (area constant), the disadvantage of the small nose radius of the 60-deg. tool becomes less, with the result that its performance overtakes that of the round-nosed tool on a cut in the vicinity of $^3/_8$ in. deep by $^1/_{32}$ in. traverse, and this not withstanding that the length of the cutting edge engaged is slightly less.

110 The 60-deg. tool showed indications of overtaking the performance of the 30-deg. tool on extremely fine traverses.

111 In the foregoing it has been maintained that in general the durability of a tool increases with the length of cutting edge engaged, but in some instances it has been pointed out that an exceptional length of cutting edge may induce chatter.

112 When considering the results of these trials it was thought that the superiority of one tool over another on any particular cut might be entirely due to the thinner shaving removed by the tool, and it was decided to compare the appropriate speed, with shaving thickness. For this comparison the 30-deg., 60-deg., and 90-deg. tools were taken. Points were chosen on a curve such that the theoretical thickness of shaving was the same for each tool, and with it the corresponding appropriate speed.

113 This process was repeated for several cuts from 0.2 in. to 0.05 in. thick, and from the results it was evident that there is a marked difference in the performance of the several tools, and that the superiority of one tool over another is not due to shaving thickness alone.

114 In the durability trials with tools of various cross-section it was observed that there is a decided increase in the life of a tool with an increase in the cross-section. This increase in life with increase in cross-section is no doubt due to the rapid dissipation into the body of the tool of the heat generated at the nose. This would result in a lower temperature, and consequent decrease in the rate of wear.

115 Durability trials when operating dry with a selected tool on different grades of steel gave the following results: A series of curves were plotted as the results of the trials and were similar in character. The appropriate cutting speeds for several cuts were also plotted as ordinates on abscissas of Brinell hardness figures and these showed a diminution in the cutting speed with increase in hardness figure. As the latter, for the grades of steel under consideration, increases almost directly as the maximum stress, the cutting speed when plotted on a base of maximum stress would be along curves similar to the Brinell-hardness-figure curves.

116 Relative to the component forces acting upon a tool and power consumed while cutting, the results observed were as follows:

A series of trials was made in order to determine the variation in the vertical, surfacing, and traversing forces acting upon a tool, under constant conditions of cutting angle, depth of cut and traverse, with change in the nose radius. The tool used had a 60-deg. plan angle and a cutting angle of 70 deg. and operated on a cut $^3/_8$ in. deep by $^1/_{32}$ in. traverse at a speed of 35 ft. per min. The values obtained in this series were plotted and the curves show that the vertical and surfacing forces both increase, whereas the traversing force diminishes with an increase in the nose radius.

Bureau of Standards Trials—Effects of Heat Treatment

117 Further work has been done on the subject of heat treatment by H. J. French, Jerome Strauss, and T. G. Digges of the Bureau of Standards, and the results of their investigations have been very ably presented in a paper entitled The Effects of Heat Treatment on Lathe Tool Performance and Some Other Properties of High Speed Steel, of which the following paragraph is a prefatory abstract.

118 This report is concerned with the time-temperature relation in the hardening and tempering of high-speed steels and their effect upon lathe-tool performance, constitution, and dimensional changes. Comparisons of endurance are also given at various cutting speeds of the four most important of the current steel types for roughing tools and the relative advantages and disadvantages of each are discussed. In addition the "Taylor" and "break-down" tests for lathe tools are compared and some of the limitations of the former are described in detail. Finally the prevention and elimination of so-called "flaky fractures" in the heat treatment of high-speed steel has been considered.

119 The principal conclusions drawn from these tests may be summarized as follows:

a The endurance of high-speed steels is affected to a marked degree by the high-heat temperature used in hardening and rises rapidly with increase above 2200 deg. fahr. However, a point is finally reached where a further temperature rise is no longer attended by a commensurate increase in the endurance, and if high enough heats are employed, a decrease will be observed coincident with a partial melting of the steel. Under otherwise fixed conditions there is therefore a high-heat temperature which results in maximum endurance, but this varies with composition. It is higher in the 18 per cent tungsten than in the 13 per cent tungsten steels and is raised in both types by the addition of 3 to 5 per cent of cobalt.

b The best hardening temperatures for the four main types of high-speed steel to be used as lathe tools under severe service, are considered to be about as follows:

2350 deg. fahr. for low-tungsten, high-vanadium steel.
2400 deg. fahr. for high-tungsten, low-vanadium and low-tungsten cobalt steels.
2450 deg. fahr. for high-tungsten cobalt steel.

These temperatures are a compromise between several factors including tool endurance and brittleness.

c The endurance of high-speed steels is likewise dependent upon and, within limits, increases with the time at high heat. In tests made with high-tungsten, low-vanadium steel, tools held 3 min. at 2280 deg. fahr. had superior endurance to those held 50 sec. at 2400 deg. fahr. but were not as good as those subjected to the lathe temperature for $1^1/_2$ min. Therefore, for consistent results both time and temperature should be controlled by suitable instruments.

d High-speed steels subjected to the severe service described were found to have endurance characteristics of the high-temperature treatment used in hardening and this was not modified to any great degree by any subsequent tempering up to and including 1100 deg. fahr. However, the higher the tempering temperatures the tougher did the steel become. Thus the most important reason for tempering in this case is not increased endurance but decrease in brittleness.

e Length shrinkage or expansion may be produced in hardening a high-speed steel from a given temperature, if this is not too high, by varying the treatment prior to hardening. This includes both preliminary annealing and the manner of heating for hardening. However, the higher the quenching temperature and the time at high heat, within limits ordinarily en-

countered in commercial heat treatment, the greater will be the expansion, or, under conditions, the less will be the shrinkage. Likewise tempering subsequent to hardening may be used to reduce original length shrinkage or expansion, but the final length will approximate the original only in certain cases. The tempering which will produce this ideal condition will vary widely in a given steel depending upon the previous history of the samples, but in no case is it possible to completely compensate for hardening changes in two dimensions

f In a series of tests on nickel-steel forgings in which the cutting speed was varied from about 45 to 70 ft. per min., high-speed steels containing about 3.5 per cent cobalt had much greater endurance than the plain chromium-tungsten-vanadium steels. Under the most severe service the low-tungsten cobalt type was superior to the high-tungsten cobalt steel, but at the lowest speeds both had comparable endurance. Comparisons of the four steels tested when based on breakdown tests, showed the following average of superiority:

	Per cent
Low-tungsten cobalt steel	98
High-tungsten cobalt steel	90
Low-tungsten, high-vanadium steel	68
High-tungsten, low-vanadium steel	47

g Low-tungsten steels with or without cobalt additions are more sensitive to heat treatment than the high-tungsten types. They are more brittle when hardened for maximum endurance but require lower hardening temperatures than do the corresponding high-tungsten steels. These features in addition to comparisons of endurance must be considered in selecting steels for particular service. No one type of high-speed steel meets all requirements, but each has its advantages and disadvantages.

h Both the "breakdown" and "Taylor" tests have limitations and cannot wholly replace the method of u ing tools in the shop to determine just what they will do. However, much worth-while information of practical value can be obtained in relatively short time by careful interpretation and correct application of results obtained by either test.

i In normal shop practice so-called "flaky" steel may be produced through the hardening of long lengths of lathe, planer, and shaper tools, followed by dressing operations in which only part of the previously hardened steel is heated to annealing temperatures which would ordinarily prevent its occurrence. As "flaked" steel is brittle and showed a tendency toward erratic results in lathe tests, its production is to be avoided.

j Prevention of "flaky" fractures in ordinary high-speed steel in heat treatment is much more simple than elimination and may be accomplished by annealing between successive hardening treatments. In no case when once produced was complete elimination effected by annealing alone, though certain complicated treatments left mere traces of this structure upon re-hardening. However, combined forging and annealing completely removed severe "flake" in all steels tested. In general, the greater the reduction in forging, the lower was the annealing temperature required for a cure (within limits).

k High-tungsten, low-vanadium steels offered the greatest resistance to the formation of "flake" and likewise to its elimination when once produced.

Lathe Breakdown Tests

120 In addition to the above-mentioned experiments, Messrs. French and Strauss conducted a series of lathe breakdown tests of some modern high-speed tool steels for the Bureau of Standards, which are of importance in that several valuable conclusions may be drawn therefrom: namely,

a Breakdown tests, in which the endurance of tools is determined under definite working conditions, are not satisfactory as the basis of purchase for high-speed tool steels.

b While competitive comparisons of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty provided sufficient tools are tested and averages of at least two grinds are used in the interpretation of results.

c In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced it was found that the performance of commercial low tungsten-high vanadium and cobalt steels was superior to that of the high tungsten-low vanadium type and special steels containing about $^1/_4$ per cent uranium or $^3/_4$ per cent molybdenum.

d Modification in test conditions, including small changes in tool angles but principally changes in cutting speed, more markedly affected the performance of steels containing cobalt or special elements, such as uranium or molybdenum, than that of the basic types (plain chromium-tungsten-vanadium steels).

e The relatively poor endurance of the high-tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these tests the performance of the cobalt steels was better than either the low- or high-tungsten steels.

121 One most interesting feature revealed in the comparison of the performance of $^1/_2$-in. by $^1/_4$-in. and 1-in. by $^1/_2$-in. tools when removing metal from the same test log under the same cutting speed, feed, depth of cut, etc., was that the small tools removed more metal than the large ones before failure.

122 The conclusions stated above are based on analyses of about 65 lots of steel, representing approximately 40 brands, produced by various manufacturers during the period 1919–1922. Comparative lathe cutting tests (breakdown tests) were conducted on about 25 brands.

123 While we recognize the importance of correct heat treatment of high-speed cutting tools and follow what is considered to be the best standard practice, we must not overlook the subject of hardness, as applied to both the cutting tool and the material to be cut.

124 A paper by R. L. Smith and G. E. Sandland on "an accurate method of determining th hardness of metals, with particular reference to those of a high degree of hardness" presented May, 1922, before the Institution of Mechanical Engineers, establishes certain desirable facts. It is of interest to note their definition of the term hardness: "Hardness is proportional to the load necessary to produce a constant-sized impression."

125 The experiment was carried out as in the ordinary Brinell method, with a 10-mm. ball, and the modified hardness numeral is taken as equal to the Brinell hardness number at 1000 kg. $\times \left(0.9 + \frac{0.4}{d^2}\right)$, where d is the diameter of the impression in millimeters. However, it was found that the results obtained in the higher ranges were far from satisfactory. There appears to be no doubt at all that this is due to the expressive deformation of the ball, and Shore,[1] in confirming this and correlating the Brinell and scleroscope scales, was able to obtain more accurate results by means of a spherical diamond the hardness of which, of course, greatly exceeds that of the hardest steel and is consequently not liable to undue deformation.

126 The authors' experiments may be summarized as follows:

a By knowing the impression given by a standard load, it is possible, by means of a formula, to obtain ball-hardness figures which are proportional to the load required to give a standard impression.

b This ball test fails at about 525 Brinell or 550 modified ball hardness.

c Such modified-ball-hardness numerals may be determined by means of an uncut diamond with a natural pyramidal point over the whole range of hardness.

Chip Temperatures

127 Following this subject of heat treating and hardness, it is of interest to note the work done by H. I. Brackenbury and G. M. Meyer and described by them in an article entitled The Heat Generated in the Process of Cutting Metal, which appeared in *Engineering*, January 13, 1911.

128 One of the most obvious of the phenomena encountered in the engineering machine shop is the high temperature of the chips produced when cutting metal by means of a machine tool, such as a lathe or planing machine. It is also obvious to the most casual observer that the temperature of the chips rises when the cutting speed is increased.

129 It is intended in the paper under consideration to investigate the rise of temperature quantitatively, and also to consider the temperature of the work from which the chips have been removed. The authors have found that many people, arguing, as they believe, from a false analogy, consider that the temperature of a piece of metal is higher if it be turned at a high cutting speed than if it be turned at a low speed, the depth of cut and feed being kept constant in the two cases.

130 Now Dr. Nicolson has deduced from the results of his experiments at the Engineering Laboratory of the Manchester University, that the work done in removing 1 lb. of chips is independent of the cutting speed, being affected only by the shape of the tool and the quality being cut. It seems highly probable that all or nearly all this work is degraded into heat, and this will be assumed in what follows:

131 Let us now consider the case of two bars of metal exactly alike in all respects, from which equal weights of turnings are to be removed, using the same depth of cut and thickness of feed but employing in the first case a low cutting speed and in the second a high cutting speed. In both cases (on our original assumption) the same number of units of heat are produced. But this heat can only appear in the following forms: viz.,

a A rise in temperature of the chips.
b A rise in temperature of the bar.
c Radiation and conduction to the air.
d Conduction through the tool to the toolholder and lathe.

132 Throughout what follows (*c*) and (*d*) will be assumed to be small compared to (*a*) and (*b*) and will be neglected.

133 Now we know from observation that the temperature of the chips produced in the second case (high cutting speed) will be greater than in the first case (low cutting speed). Hence it follows that less of the heat goes to raise the temperature of the bar in the second case than in the first. Therefore the bar which is turned at a low cutting speed will have a higher temperature than that which is turned at the high cutting speed. We are led to the same conclusion if we approach the question from a somewhat different point of view. The work done by the lathe will be turned into heat at the point where the chip is sheared and torn from the mass of metal. If the turning be done at a high speed, this heat will have less time in which to be conducted into the bar than if a lower cutting speed be used. Therefore, if the total number of units of heat produced in the two cases be the same, the bar turned at the higher speed will have the lower temperature.

134 This conclusion appeared somewhat paradoxical, and contrary to the ordinary opinion of the shops, so that the authors considered that it warranted experimental investigation. As will be seen later, the few rough experiments which they were able to carry out fully confirmed the theoretical conclusions. It is to be hoped, however, that further experiments will be tried.

135 If we take the force exerted on a lathe tool as being equal to 100 tons per square inch of cross-section of the cut, we are led to the following quantitive results:

136 However great the cutting speed, the temperature of the chips cannot exceed a certain maximum. For, let

A = area of cut in square inches. Force on cut = 100 A tons.

[1] *Jour. Iron & Steel Inst.*, 1918, No. 2, p. 59.

Specific heat of steel = 0.11. Density of steel = 0.284 lb. per cu. in. The work done per inch of cut

$$= \frac{100\,A \times 2240}{12} \text{ ft-lb.}$$

Taking 778 as the mechanical equivalent of heat we have:
Heat produced per inch length of cut

$$= \frac{100\,A \times 2240 \text{ B.t.u.}}{12 \times 778} = 24\,A \text{ B.t.u.}$$

But the weight of the chip per inch length = 0.284 A lb. Therefore, if all the heat goes into the chip, the rise of temperature

$$= \frac{24\,A}{0.11 \times 0.284\,A} = 770 \text{ deg. fahr.}$$

137 Variation of temperature of chip with cutting speed. Let

T = rise of temperature of chip.
A = area of cut in square feet.
Q_0 = total heat produced per second.
Q_1 = heat conducted into the bar per second.
Q_2 = heat carried away in chip per second.
V = cutting speed in feet per second.

Take the density and specific heat the same as before; then

$$Q_0 = \frac{144 \times 100 \times VA \times 2240}{778}$$
$$= 41{,}500 \times VA \text{ (B.t.u.)}$$
$$Q_2 = AV \times 0.284 \times 0.11 \times 1728 \times T$$
$$= 53\,VTA \text{ (B.t.u.)}$$

138 The quantity of the heat conducted to the bar per second depends upon the temperature of the bar, the temperature of the chip, and the dimensions of the cut. The temperature of the bar will be nearly the same for all cutting speeds, so that as a first approximation we may take

$$Q_1 = MTA$$

where M is a constant depending on the particular case, but independent of the cutting speed. We have then

$$Q_0 = Q_1 + Q_2$$

assuming that the radiation to the air is small. Therefore

$$41{,}500\,VA = MTA + 53\,VTA$$

and

$$T = \frac{41{,}500\,V}{53\,V + M}$$

Putting V' = cutting speed in feet per minute,

$$T = \frac{690\,V'}{0.9\,V' + M}.$$

139 This constant M must be obtained by experiment; so that, supposing the theory to be sufficiently accurate if we know the temperature of the chip at any given cutting speed, we shall be able to foretell its temperature at any other cutting speed (keeping the feed and depth of cut the same).

140 In order to test these theories, several experiments were made. The temperature of the chips cannot be found directly, therefore they were allowed to fall into a vessel containing water and the rise in temperature of this water was noted.

141 From this and the known weights of the water, the vessel, and the chips, and their specific heats, the original temperature of the chips at the time of their immersion in the water was calculated. A similar course was pursued to find the temperature of the bars Throughout the initial temperature of the water was nearly equal to the temperature of the atmosphere, and the quantity of it was such that its rise of temperature never exceeded 18 deg. fahr. so that radiation should be reduced to the minimum. The thermometer used was graduated to 0.5 deg., and could be read to 0.1 deg. fahr. by estimation.

EXPERIMENTS TO DETERMINE VALUE OF *M*

	I	II
Initial diameter of bar, in.	9 5/8	9 5/8
Final diameter of bar, in.	9 1/4	9 1/4
Depth of cut, in.	3/16	3/16
Feed per inch	12	12
Speed, ft. per min.	31.6	13.8
Weight of chips	6 lb. 4 1/2 oz.	7 lb. 2 1/2 oz.
Temperature of chips, deg. fahr.	617	468
	III	**IV**
Weight of bar before turning	7 lb. 13 1/2 oz.	7 lb. 13 oz.
Weight of bar after turning	6 lb. 11 1/2 oz.	6 lb. 12 oz.
Difference	1 lb. 2 oz.	1 lb. 1 oz.
Temperature after turning, deg. fahr.	117	93.6
Temperature of air and bar before turning, deg. fahr.	64.25	64.25
Speed, ft. per min.	11.3	88
	V	**VI**
Revolutions per minute	24	188
Cutting speed, ft. per min.	9.65	75.4
Initial weight of bar	6 lb. 8 oz.	6 lb. 7 1/2 oz.
Final weight of bar	5 lb. 9 1/2 oz.	5 lb. 10 1/2 oz.
Weight of chips	14 1/2 oz.	13 oz.
Weight of chips collected	14 oz.	10 oz.
Temperature of bar, deg. fahr.	108.5	95.4
Temperature of chips, deg. fahr.	479	806
Temperature of air and bar before turning, deg. fahr.	64.25	64.25
Heat in job, B.t.u.	26.7	19.3
Heat in chips, B.t.u.	41.4	66.3
Total heat produced, B.t.u.	68.1	85.6
Heat produced per pound of chips, B.t.u.	75	105

142 From experiment I we find M = 10.6, which gives the temperature in experiment II as 473 deg. fahr. This is an extraordinarily close approximation.

143 Experiments III and IV were designed to test the truth of the theory that with high cutting speed the temperature of the bar would be lower than with low cutting speed. The same tool was used in both cases without resharpening, and the slower turning was performed first, so as to give it the benefit of the sharper tool, which presumably would heat it less. The tool was considerably dulled at the higher speed, which accounts for the slightly less weight turned off.

144 Two cuts were taken. The driver was removed before immersing the bar in water. This was done so as to be able to use a smaller volume of water. The driver could be taken off in less than 10 seconds without touching any part of the bar, except the small center.

145 It may be seen, therefore, from experiments III and IV, that, as was expected, the bar is the cooler which was turned more quickly, other things being the same. The small difference of about one ounce in the weight of the chips was due to the tool becoming blunter in experiment IV, and is quite insufficient to account for the difference in temperature of the bars, especially when we consider that, owing to the blunter condition of the tool, more pressure per square inch area of cut would be required to remove the cuttings in experiment IV than in experiment III.

146 The bar turned at the lower speed had, obviously, more time in which to get rid of heat to the air. The water into which the bar was dropped rose in temperature from 64.25 deg. fahr. to 67.9 deg. fahr. in experiment III, and from 64.25 deg. fahr. to 66.3 deg. fahr. in experiment IV. It will be seen that the rise of temperature in the two cases is more than 1.60 deg. fahr.

147 In experiments V and VI the temperatures of both the bar and the chips were found. Two cuts were taken as before.

148 The temperature of the water into which the bar was dropped rose from 64.25 deg. fahr. to 66.85 deg. fahr. in experiment V, and from 64.25 deg. fahr. to 66.1 deg. fahr. in experiment VI. The difference between the rise in these two experiments is more than one graduation on the thermometer.

149 Now if H be the total heat produced in B.t.u. per pound of metal removed, we have:

Work done per pound = $H \times 778$ ft-lb.

Volume of 1 pound of steel = $\frac{1}{490}$ cu. ft.

$$\therefore \text{ Cutting force per square inch } = \frac{H \times 778 \times 490}{144 \times 2240} = 1.18\,H \text{ tons.}$$

This assumes that the work done in feeding the tool is negligible and gives:

Experiment	V	VI
Cutting force in tons per square inch	88.5	124

150 From experiment V, M = 7.3, so that in experiment VI the temperature of the chips should be 754 deg. fahr., which is close to the observed temperature, 806 deg. fahr.

151 It will be seen in the last two experiments the cutting force per square inch is in one case less, and in the other greater, than the value assumed, namely, 100 tons per sq. in. It will be seen in the last two expreimehts the cutting force per square inch is in one case less, and in the other greater, than the value assumed, namely, 100 tons per sq. in. It follows, therefore, that the formula calculated on this assumption does not apply accurately, and, in fact, the difference between the observed and calculated temperatures in experiment VI is 52 deg. fahr.

Action of Cutting Tools

152 The mode of action of cutting tools has been the subject of much investigation on account of its great importance to engineers, but so far it has apparently not been studied by photoelastic methods. A paper presented by Prof. E. G. Coker and Dr. K. C. Chakko before the Institution of Mechanical Engineers gives "An account of Some Experiments on the Action of Cutting Tools."

153 The subject of this paper is based on the principles that nearly all transparent bodies when loaded become doubly refractive, and a ray of ordinary light passing through the material in a state of stress is subjected to a selective retardation whereby its transverse vibrations lay one behind the other. No effect is visible to the eye, since ordinary light consists of such a complex system of transverse vibrations that the eye is unable to detect what is going on, but if ordinary light is, as it were, strained through some kind of a sieve whereby a homogeneous character of a particular kind is imparted to it, the effect of stress in the material becomes apparent. The most convenient apparatus for obtaining the homogeneous light mentioned above is a crystal of transparent calcium carbonate, cut in a special way invented by an Edinburgh optician, William Nicol. Ordinary light, after passing through such a crystal is found to execute its transverse vibrations in one special plane, and this unilateral kind of light is usually called polarized light, and although this is not a very happily chosen designation, yet it seems to be so firmly established that it is hardly possible now to replace this term by a more appropriate one.

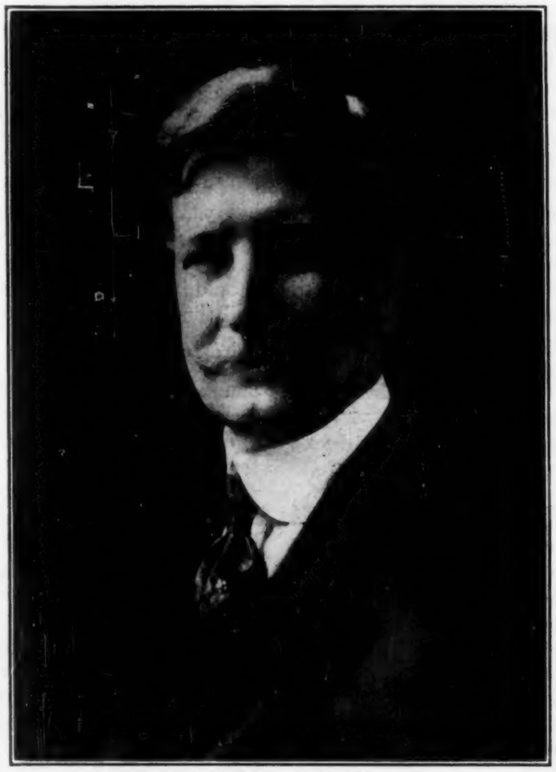
154 If a stressed body is placed between a pair of Nicol's prisms and a beam of light is passed through the combination, color effects are observed, which are due to the fact that the plane polarized light from the first prism is broken up by the stressed material into two sets of plane vibrations of light, which travel at different velocities through the material. Not only do these two systems of waves travel at different velocities, but they vibrate in planes at right angles to one another. Interference between two sets of light waves in the same plane is visible to the eye, when the light passing through the

(Continued on page 57)

The Engineer: His Abilities and His Public Obligations[1]

By JOHN LYLE HARRINGTON, KANSAS CITY, MO.

ENGINEERS have existed in all ages and civilizations as their works abundantly disclose, but until very recent times engineering was an art rather than a science, and engineers were considered superior artizans, rarely deemed worthy of note by the writers of history. They belonged to a class inferior to the warrior king and his nobles, the priest, the lawyer, and the physician, all of whom figure materially in the records. In considerable measure engineers are still looked upon and still regard themselves as glorified mechanics. Many still rise by self-education from the ranks of the artizans to high place in the profession. In a recent address to The Institution of Civil Engineers one of its eminent members said: "Engineers. . . . . . have, most of them, owing to the very wise system of their training, had experience in manual work, have worked side by side with men who are now merely wage earners." Though for more than fifty years engineers in increasing numbers have been graduated by schools of the highest standing, though their scholastic training is quite as long and severe as that required for the other learned professions, something of the old view of the profession still remains in the public mind. It requires centuries to change a commonly held view, to break down long-established prejudices, but sometimes a cataclysm hastens the process. The great war was such a cataclysm, for it brought home to the public in spectacular manner the fact that modern warfare rests squarely upon industry, and both upon engineering; therefore it materially raised the profession in public esteem.



Past-President John Lyle Harrington

Yet there is something lacking. Engineers find it necessary to insist upon the fundamental character of their profession, to point out and to discuss its essential qualities, to call attention to the sound training required in preparation for it; then, to deplore its lack of recognition, its inadequate rewards in money, place, and honor, and to argue the means of obtaining them. They resent the views so often expressed or implied that the engineer is hardly a scientist, is at most a technician, useful in a narrow sphere but of small value in the important fields of business, finance, and government. In the public mind he is still commonly pictured in khaki, high boots, and a broad-brimmed hat, bossing the job, a worker rather than a thinker. He has secured a foothold in the management of engineering enterprises, but grudgingly and not so generally as he believes to be his due. And while there are abundant examples, cited with pride, of engineers at the head of railroads and constructing and manufaturing enterprises, the number is still comparatively small. In general, the public does not feel certain of the engineer in such positions, does not quite expect to find him there. The financier rarely relies upon him in business, except as an officer of a corporation, where he is guided and supported by business men. It is believed that his knowledge of business and finance is inadequate for safety, that he is something of an optimist and a dreamer, unable to see the pitfalls in a project, unable to evaluate the business element of it, and therefore an unsafe guide for the investor of money. In government the engineer is entrusted with technical matters only, leaving business matters to business men and the dominating political matters to politicians, who hear and sometimes heed the voice of the people, who consider the requirements and determine what is best from the broad, political point of view, untrammeled by the idealism, directness, and honesty of the engineer.

The Need of the Engineer in Government

Our country is still governed by the military and the legal professions, influenced somewhat by the business man. Every president, except Harding, has been a general or a lawyer, while the latter not only occupies his peculiar field, the judiciary, but dominates in the legislatures and in the executive branches of the Government. These facts have materially retarded the progress of political development, for the lawyer lives by precedent. His eyes always upon the past. It results that we progress slowly, that order and rule are deemed more important than service and progress. The engineer with his constructive, creative, scientific mind is sorely needed. His preparation should be broadened so that he may deserve and receive the same public confidence in his human qualities and in his understanding of business and economic and political matters that is now given to his honesty of purpose and to his scientific knowledge. His ideals should be turned more away from himself and his immediate interests and should include appreciation of his obligations to give liberally of his talents, his time, and his energies to the broad service of his community and his country. He should come to understand that by coöperating unselfishly with his fellows, individually and through his technical societies, he is doing his most to advance the interests of his profession and of his country; that he is developing the high professional consciousness which will give his profession cohesion, weight, and influence in proportion to its potential deserts.

Shortcomings of the Present Educational System

Engineers owe their profession and the country thorough consideration of the essentials of that education which will bring engineers to their fullest development; to education in the collateral subjects so essential to their broadest usefulness. They are fully aware that the future position of the engineer will be determined largely by the plan of engineering education; that the present technical education does not meet all requirements; and the investigation into the matter now about to be made should solve the problem and serve as an example for other investigations of far-reaching character.

But engineers cannot stop there; since they play an increasingly important part in industry, since the welfare of the workers is largely in their keeping, it is their obligation to determine and to bring into use the type of education for workers most conducive to their usefulness to society and to themselves, and consequently to their greatest happiness and highest development. Our educa-

[1] **Presidential Address at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers.**

tion was initially planned to be cultural only; the individual secured his vocational training by apprenticeship or by chance, and we continue, with trivial exception, to train all youth culturally but to leave to fortune training for their economic place in life. We glorify mental labor and train away from work with the hands till Americans consider it degrading, socially inferior, and suitable only for the ignorant, the immigrant, or those of low mentality. The trade unions restrict apprenticeships and the schools offer little education in the trades. Apparently it is expected that the native American, with his superior cultural education, will make his way by his wits without soiling his hands. He is barred by his false social ideals and by his lack of training from those profitable and honorable fields of industry which involve manual labor. Girls are so taught that they look down upon the man who works with his hands. Engineers know these conditions and know their detrimental effect upon men and upon the economic welfare of the country. It is their obligation to present the truth and to press for the reform of our educational system to conform to it. They are not, in general, educators, but they know the need for educating men for industry and they should lead in the endeavor to secure it. The employer is not to be blamed if he demands that the door be opened to foreign labor when he finds it impossible to satisfy his requirements at home. We have seen the building trades throttled, our housing needs unsatisfied, by the extravagant labor costs resulting from restrictions in training and apprenticeship so severe that these crafts will almost die out with the present generation of workmen.

Engineers are applied scientists, but they have been leaving to private interest or individual initiative the research work in their field. In very recent years they have set up some agencies which have begun to function, but their efforts have not always been so successful that the ability of engineers in this line may be considered brilliant; neither have they demonstrated their ability to coöperate with other research organizations not strictly engineering in character. It is all very well to assume that the engineer fully understands just how engineering research should be conducted, that he can do it better than any one else, but the correctness of these views is yet to be determined. The evidences are not all in the engineer's favor.

The Engineer's Aid Needed by the Economist

The engineer has created modern industry, has been responsible for a production of goods that in this country is substantially sufficient, if other factors were in accord, to establish the universal comfort and well-being that the race has sought since the beginning. But the engineer has been so intent upon devising means for production, upon improving quality of product, and upon managing the men and tools of production to secure the maximum results that he has failed to develop his ability and to establish his position in the other leading factors of life, to which he is entitled by virtue of his part in production and the resulting welfare.

One of the greatest causes of unrest on the part of the worker lies in his lack of understanding of the value of the other factors necessary between the basic raw materials and the consumer of goods. The engineer, in his present position of impartial technician, ought to be the agency to determine what should be the difference between the cost of production and the cost to the consumer, of exposing the truth and righting the errors and abuses now existing, then of showing labor what is its just portion.

The whole business of the country may be likened to a sea on which there are extremely high and low tides at rare intervals; regular and moderate tides at frequent, definite intervals; long ground swells coming from distant disturbances; small waves often violent and destructive, resulting from local causes; but all clouded in mystery to any but the seawise. Capital and men flow from the less to the more profitable branches of industry until the rush coming in from all sides brings overproduction, stagnation, loss, and finally readjustment to the studied and understood needs. These shifts go on in every industry, consequently the balance is never complete, and some industries are very prosperous while others are greatly depressed and the remainder range between. Business men have little faith in the engineer in business; but his scientific methods applied to those problems of business which are too complicated for the business man's solution by judgment, should result in better understanding of the fluctuations in business and their causes, and finally in remedies which would greatly alleviate, if not cure, the fluctuations which cause panics and unemployment. At the moment the most completely industralized nation, with all its machinery of production intact, highly organized, amply financed, at peace, is unable to adjust itself to existing conditions; two millions of its workers are idle; more than a million and their dependents are scantly sustaining life on a dole taken by taxes from capital and the earnings of the employed. This nation will muddle through, but scientific principles applied with broad consideration of all factors should prevent such a disastrous breakdown in industry. Countries, like men, sometimes find themselves unable to cope with unforeseen factors, but generally the causes of depression are apparent after the fact, whereas scientific study should disclose them in advance and permit preventive rather than remedial measures to be applied. The engineer should turn his attention to these matters and aid economists to solve the vital problems.

The Engineer and Transportation Problems

The engineer has already established the fact that he and his methods can secure efficiency in industry and great reduction in the cost of production; and, since the railroads are no longer the football of speculating financiers, the engineer's services are producing beneficial results in transportation. Much remains to be done in the means of transporting goods by water and rail, while the newly developed business of trucking and the hardly touched business of combining the truck with rail and water transportation has yet to be worked out. The combination of means and the proper adjustment of them to the need for low cost or for quick delivery or for both have still to be established. Means which should be supplemental are now more or less destructively opposed, and the engineer is sorely needed to bring about the economies of harmony.

Water transportation, especially on our inland waterways, is ineffective, practically non-existent, because sentiment and commercial-club types of effort have prevailed instead of sound economic and engineering methods. The problem of inland water transportation lies largely in the handling of materials to and from vessels, purely an engineering problem, whereas public attention has commonly been directed toward depths of channel and establishment of boat lines to the neglect of terminal facilities.

The cost of doing business, that is, the taking of goods from the producer and delivering them to the consumer, is in many industries greatly out of proportion to the service rendered. The orchardist who purchases and prepares the land, plants, cultivates, trims, and cares for his trees for seven years before they come into production, then sprays, picks, packs, and markets his fruit, is throughly convinced that the business of distribution is unwisely handled when he sees the consumer pay four to five times as much as he receives for his product. The apricot growers of California know somebody blundered when they were paid $150 per ton for their fruit one year while the next they were without a market because the canners did not sell the previous year's pack. In all such industries the entire risk is thrown upon the producer because he is less well organized than the merchant, but the whole problem of marketing needs scientific study.

Scientific Fact Finding the Engineer's Prerogative

The judgments regarding the ability of the market to receive and pay for goods are unscientific and too generally defective. We now have capacity for making automobile tires quite out of proportion to the need for them, of producing coal far in excess of the country's requirements; we are producing wheat in much greater quantity than the markets of the world demand, and at many points industry is out of balance. There is no sound objection to the doctrine of *laissez faire;* it is probably unwise to try to curb the freedom of the initiative of the individual or of the corporation in honest business; but scientific fact finding, the engineer's prerogative, employed before the venture is made, would save both capital and labor from disastrous results. The judgment of the business man could well be supported by the engineer's science.

Sound and scientific adjustment of industry, based upon knowledge of all the facts, would prevent the great diversity of reward

among those engaged in fundamental industries. It is difficult for one of the unorganized laborers and tenant farmers of the South, who rarely receives in a year as much as $400 in money and goods and the rent of a poor house for the labor of himself and his family, to believe governmental agencies to which he contributes through taxes are justified in requiring the railroads to pay four times this sum to the average railroad worker of the same locality on the theory that it is essential to proper standards of living. If the Government were scientifically administered all facts would be available, and equity as between industries and localities would be reasonably well secured.

The Engineer and Public Business

Engineers have not until recently disclosed an aptitude for public business and governmental matters. They have followed the habit of employees and devoted themselves to the interests of their individual employers. And with that lack of ability to coöperate with each other for which they have acquired an undesirable reputation, as evidenced by the multitude of their organizations as compared with those of other professions, they have only recently begun to employ their special talents in the public service. The investigation of the twelve-hour day disclosed the truth, and results naturally followed. The investigations and reports made by interested business men or disinterested sentimentalists accomplished nothing, because they were biased and therefore not generally accepted; but the engineers' report carried with it conviction of ability to determine and honestly to state the facts, hence it was promptly accepted and acted upon.

It naturally follows from the engineer's custom of dealing with the unalterable laws of nature that he generally presents the facts as he finds them. It is, of course, not uncommon for the engineer in subordinate positions to color the facts to suit his employer's interest, but it is less common than in business or in other professions. It is the engineer's habit to be fair between client and contractor, between buyer and seller, between employer and employee, between capital and labor; and on account of this custom, born of his scientific methods and habits, he is better fitted than any other to bring capital and labor together on a sound basis and thus to stop the enormous waste their quarrels now cost. Management is by no means free from the mind of the feudal lord; and labor is too generally dominated by leaders who make a living out of making trouble, out of endeavoring to secure for labor more than its just share of the goods its helps to produce and, for labor in his particular industry, more than its just share of the total earnings of labor in all industry. Out of ignorance or cupidity, labor leaders too often distort the facts, while management at times, by secrecy or deceit, secures too great a share for capital. The result is distrust, unfair demands, strikes, lockouts, and loss to both parties and to the public. The facts set forth impartially after the methods of the engineer would greatly reduce if not eliminate these bad practices.

It is not the purpose to argue that the engineer is the one logical man to perform all industrial functions, that he should entirely replace the lawyer as an adviser, that he should take over all the functions of the business man, that he should replace the financier, or that he should take over the functions of government, beyond the extent to which his place in industry and his peculiar fitness makes wise; but it is imperative before we proceed much further that the engineer perform his proper part and office in all these matters.

Engineers in municipal government, which is chiefly engineering and business, are demonstrating their worth. They come to the work with unusual equipment: technical knowledge, honesty of purpose, the creative mind; but the world is reluctant to admit that they have the business and the political qualities essential to the work. It is usual to thank fortune that engineers are not politicians, to deprecate the services of politicians because they are too commonly spent for the politician instead of the public; but though a politician is usually one who is in politics for private advantage, he may be one skilled in political science and administration; and if the engineer be equipped in this latter sense also, he should be an ideal municipal public servant.

In state and federal matters engineers have only recently ventured beyond their technical field. A whole administration of the Federal Government apparently subscribes to or at least acquiesces in the view that an engineer is not equipped to administer an engineering bureau or to conduct business affairs founded on engineering. It is true that this is politics of the questionable kind, but the lack of public confidence in the engineer's business and administrative ability makes possible its success. No one is disturbed about it but the engineer.

The United States developed in a century from an agricultural nation in which each household produced its own food and manufactured nearly all the goods necessary to satisfy its needs to a highly organized industrial nation producing goods of all kinds in quantity and at a price never before known, though wages in terms of money or goods or benefits are not equaled in any other country. The engineer has enabled the industries of this country to compete in the markets of the world with the handicraft nations with their vastly lower standards of living. We are too prone to congratulate ourselves on our progress, to be content as a whole people with the successes we have achieved, forgetting that in the warring of the groups or divisions of industry the individual, sometimes whole groups, frequently suffer; but there is always a material element of society which is too weak to hold its place; and in sacrificing it we are sacrificing the whole well-being of society. It is not a solution of the problem for the strong to halt long enough to give of their production to the weak: that is but a sop to man's sense of responsibility for his brother; the strong are obligated to help the weak to help themselves, to curb the predatory, and to bring to a higher level the lowest standards of living.

The engineer is a scientist trained in the application of the scientific method to all his problems, accustomed to determine and to be guided by the truth. It is his part to determine and present for the use and enlightenment of the public the whole truth about the industry he has created. When business, through greed or ignorance, abuses industry, a clear exposition of the facts is the surest means of setting the matter right. When self-seeking politicians attack industry for their own benefit but to the injury of the industry and the country, it is the obligation of the engineer, individually and through his organizations, to present the facts which will set the public mind straight. The energy to determine the truth and the courage to present it will go far toward curing the evil.

The Engineer Politically Weak

In some cities we see organized engineers consulted and heeded in civic matters; in others we see them utterly ignored in the expenditure of public funds in works with which the engineer is particularly qualified to deal. Politically the engineer is weak because he rather expects his opinion regarding engineering matters to be accepted by the public and by politicians simply because his professional knowledge enables him to speak with assurance. He fails to appreciate that it is not enough to know, to be right, but that he must present his views with vigor and true political wisdom if they are to be adopted.

Because the engineer rarely presses his view on the public or upon the business organizations with which he is associated, he likes to think he is modest. He likes to sit in the background till deference is shown to his superior technical knowledge by calling him into conference. Too often the reticence he considers modesty springs from lack of confidence in his ability to present his views convincingly; for he commonly knows that he is weak in forensic and political ability. Is it not possible that his modesty is really pride in his technical knowledge and fear that he is unable to enforce his views?

The Engineering Profession Ineffectively Organized

The engineer considers himself competent to organize certainly industry, possibly business and government, but he has not demonstrated the ability to organize most effectively his own professions. Instead of one comprehensive organization designed to deal with the social, the welfare, the professional, the research, the standardizing, and the public-service matters with which engineers are concerned, groups have formed many societies busied principally with professional and social matters. Intolerance or lack of foresight or inability to get on with their fellows caused each group to seek opportunity for self-expression by forming a separate organization devoted to the particular, narrow interests of the group. The splitting-off process continues and will continue unless the engineers awake to the harm it is doing. Engineers, more than any other

group, find difficulty in composing their differences, in harmonizing their efforts. The four great founder societies are learning to work together, somewhat as a result of the efforts of the great iron master, but harmony has come slowly, and not without jealousy and suspicion. The lesser groups are more or less ignored and some of the newer ones are materially antagonistic to the older organizations. The differentiation should never have taken place; the profession should have developed within one all-inclusive unit, which, by members, by its ability to speak for all engineers, as the Bar Association speaks for all lawyers, could exert the whole weight of the profession in industry and in public affairs.

The profession is not yet entirely differentiated from the trades from which it arose. It is true that within fifty years great numbers have been graduated from our technical schools and been received into our engineering societies with that guarantee of their training, but so many competent men are still self-educated that our engineering societies provide for their admission to membership. The only assurance obtained regarding the character of their professional training and regarding the fitness of all candidates for the higher grades of membership, is the possible view of five members of the society, whose opinions may be more generous than sound. We have need for every grade of engineer and rightly have appropriate grades of memberships in our principal engineering societies. The British societies receive proportionately fewer university-trained men, hence they assure themselves of the candidate's fitness by requiring that he pass an examination into the sufficiency of his professional knowledge to warrant giving him the professional status membership confers. Engineering societies in this country might well pursue a like course, so that membership in any grade will establish the professional status with a higher degree of assurance.

Licensing and the Status of the Engineering Profession

Opinion is greatly divided regarding the advisability of making engineering a closed profession, or fixing by legal license the professional status of every private practitioner and every engineer employed by others. The leading proponents of license laws advocate such meager requirements that the license may be had by any one calling himself an engineer. Many of the states which require engineers to be licensed make the tyro and the expert equal before the law, make the license meaningless and add to the present confusion in the minds of laymen. A few states require examinations and records that expose the real engineering status of the licensee. Engineers complain that unqualified men assume the title, and often, through ignorance of the employer or design of public officials, attain the place of qualified men to the distinct harm of the profession. It is established that the only way to prevent the unqualified from assuming the name and claiming competence is by closing the profession, as has been done in law and medicine; but it is argued, and with reason, that the creative mind is not an academic matter; that this will bar from service many good men whose natural ability and whose training in certain narrow lines fit them well for limited service. It is further argued that it is not practicable for a license to show the specific fields within which the licensee is entitled to practice. That is true in law and medicine, but no great difficulty flows from it in those professions. If licenses are graded, much as the members of the founder societies are graded, if they show the principal divisions of engineering in which the licensee is authorized to practice, if they are granted only after suitable examination and are uniform in requirement and reciprocally accepted among the states, the license will improve the status of the profession without placing undue hardship upon its members.

The profession must cleanse itself of bad practices. The fundamental principles of its ethics are well understood and clearly enunciated, but our codes offer limited control because they are administered, if at all, by committees of our societies who are loath to take on the functions of judge and executioner. Cases of infraction are rarely clear and unequivocal, and some kind of hearing or trial is essential to establishment of the facts. The injured party will rarely subject himself to the criticisms, annoyance, and loss of time this entails. It results that he complains privately but takes no steps to secure justice, and the violator of the code is encouraged to repeat the offense. If the trial body were better established and clearly performing a public duty, as would be the case if a licensing board formed the tribunal, the situation would be greatly improved, in so far as the flagrant abuses are concerned.

The profession would, however, still have the difficult duty of purging itself of petty jealousies, of unfair or otherwise improper criticism. It is impossible entirely to suppress these evidences of the weakness of human kind, but by constant endeavor they can be greatly reduced, as they are in the older professions. Thorough attention in the schools to instruction in ethical standards, constant reiteration of them in the professional societies, will increase their observance and enhance the character and position of the profession.

Engineers Must Address Themselves to All the Broader Problems of Industry

To gain the position in the business and financial fields to which the profession considers itself entitled, engineers must cease to deal so exclusively with technical problems and address themselves to all the broader problems of industry. The line between technical and business matters cannot be sharply drawn. The engineer has entered the field of management, and the rewards and the respect for his abilities are appearing. He must go further, and deal with the problems in sales, markets, and the financial structure of the industries in which he is engaged, and become a partner rather than a subordinate in the business.

But in the broad study of industry as a whole as it affects the nation and the world the engineer should have an important part. He should contribute largely to the solution of the problems of the equalization of industry; of preventing inflations and depressions, for they are complementary; of encouraging development in lines in which competent investigation shows it will be rewarded; of retarding those lines which show a tendency to excessive development. This can best be done by a thorough analysis of the factors entering into the problem and publishing the results to the world. The profession should resolve itself into a fact-finding and publishing organization in all matters pertaining to the industry with which it is associated.

Along with this, the profession through its individual members and through the coöperative efforts of its organizations must deal with politics, for government has great influence upon business and industry. The engineer, individually, must do his full political duty, must bear the onus of standing for office, must enter the political contest as the members of other professions do, and must give freely of his time and special knowledge in the public interest. He must forget his modesty and fight for place and authority if he is to receive them and render service.

And when the importance of the matter to industry or to the public welfare warrants, the whole weight of the organized profession should be employed to secure wise administrative or legislative action. Engineers have as much obligation as any other group to urge the adoption of their views in matters of their particular knowledge and interest. The profession must seek to serve the nation thoroughly, unselfishly; must give freely of its means and of the time, energy, and knowledge of its leaders, who must be supported by the engineering organizations acting together for the common good. The profession must not wait to be invited into the councils of nations, but must make its opportunities and its place. Public service should be rendered with reasonable modesty, leaving to the fairness of the public mind recognition and appreciation of it. To do this it is essential that engineering organizations put aside pride and prejudice and bury all differences in service. They may preserve their individuality in all matters of their particular interest, yet join without reservation in some acceptable plan in all matters of common concern, forgetting everything but that there is service to be rendered and that the entire weight and talent of the profession can perform it to the best advantage of all.

Engineering is a young profession and is still in a state of flux. It is not bound down to tradition nor to precedent, but has the virility of youth; the courage, the energy, and the orderly and creative mind essential to the solution of not only its own problems, but of all the great problems of the industrial world. Those problems are both technical and economic, and upon their satisfactory solution the prosperity and the peace of the world and the progress of the race depend. The responsibility is great, but we proceed with confidence that the profession will ably meet its obligations.

Forty-Fourth Annual Meeting of A.S.M.E.

Stresses Forest Conservation and Hydroelectric Development—Second National Power Show Parallels Eighteen Technical Sessions—Many Committee Meetings, Excursions and Entertainments Round Out a Week of Outstanding Events

THE FORTY-FOURTH Annual Meeting of The American Society of Mechanical Engineers was featured by a diversified program of eighteen technical sessions, supplemented by thirty-four committee meetings and numerous entertainments and excursions. The meeting extended from Monday, December 3, through Thursday, December 6, and was paralleled by the Second National Exposition of Power and Mechanical Engineering which continued through until Saturday, December 8. The registration reached a total of 1852, and the comments of those in attendance were generally enthusiastic regarding the interest of the program, the high character of the papers, and the pertinence of the discussion.

The presidential address of John Lyle Harrington on Monday evening was very well received. His dispassioned analysis of the opportunities, abilities, and obligations of the engineering profession should furnish an effective stimulus to the members of the Society. The address appears in full in this issue of Mechanical Engineering. Following the presidential address two awards of the A.S.M.E. Medal were made. The 1922 Medal was given to Frederick A. Halsey for his invention of the premium system of wage payment and the great improvement resulting therefrom in the relations between employers and workmen. The 1923 Medal was awarded to Past-President John R. Freeman for his eminent service to engineering and manufacturing by his meritorious work in fire prevention and the preservation of property. The A.S.M.E. Medal is awarded for notable inventions or striking improvements in connection with industry.

Underwood & Underwood

Fred R. Low — President, 1924

The American Society of Mechanical Engineering

It is a difficult task to determine which of the sessions at the Annual Meeting were the more interesting. Each was of particular value to some group of members and all were very well attended. Two general sessions were held, one on Wednesday afternoon, December 5, sponsored by the Forest Products Division, being devoted to the topic of Reforestation and Timber Conservation. John W. Blodgett, President of the National Lumber Manufacturers' Association, made an effective presentation of his address on this subject, which gave a clear picture of the issues involved in reforestation and timber conservation and made constructive suggestions for their advancement. Mr. Blodgett's address will appear in the February issue of Mechanical Engineering.

On Wednesday evening, December 5, the American Society of Civil Engineers and the American Institute of Electrical Engineers coöperated in the joint session on the Fundamentals of Hydroelectric Development. Lewis B. Stillwell, Past-President of the A.I.E.E., presided, and the principal speaker was John R. Freeman, Past-President of the Am.Soc.C.E. and A.S.M.E., whose address appears as the leading article in this issue of Mechanical Engineering. Formal discussions were presented by John P. Hogan, representing the Am.Soc.C.E.; Geo. A. Orrok, representing the A.S.M.E.; and Harold W. Buck, representing the A.I.E.E. These discussions from the floor are also reported in this issue. The program for this session was arranged by a committee made up of representatives of the three societies and consisting of Geo. A. Orrok, Am.Soc.C.E., Clavert Townley and L. F. Morehouse, A.I.E.E., Fred R. Low and Joseph W. Roe, Chairman, A.S.M.E.

The first official business of the meeting was a meeting of the Council on Monday morning, December 3, at which the Local Sections' Delegates were present. President Harrington and Dean Kimball made concise statements of the reasons why the Council had deemed an increase of dues advisable and necessary. After the withdrawal of the Local Sections' Delegates the Council passed a strong resolution in favor of the reduction of taxes on earned incomes, endorsing the recommendations of Secretary Mellon and urging upon Congress the amendment to the Internal Revenue Act proposed by him. The Council suggests that each member of the Society directly request his local congressman and senator to vote in favor of the proposed tax amendment. Other routine business was transacted.

On Friday morning, December 7, the new officers of the Society were installed and the incoming President, Fred R. Low, was presented with the gavel as a symbol of his authority. The other officers who took office at this time were Vice-Presidents George I. Rockwood, W. J. Sando, and H. Birchard Taylor; Managers, E. O. Eastwood, E. R. Fish, and Frank A. Scott, and Treasurer William H. Wiley.

The meeting of the Local Sections' Delegates was given over largely to a discussion of the increase in dues which had been broached by President Harrington and Dean Kimball at the opening of the Session. Delegates from the following A.S.M.E. Sections were present: Akron, Atlanta, Baltimore, Birmingham, Boston, Bridgeport, Buffalo, Carolinas, Central Pennsylvania, Chattanooga, Chicago, Cincinnati, Cleveland, Colorado, Columbus, Detroit, Eastern New York, Erie, Green Mountain, Hartford, Houston, Indianapolis, Inland Empire, Kansas City, Knoxville, Los Angeles, Lehigh Valley, Louisville, Meriden, Mid-Continent, Metropolitan, Milwaukee, Minneapolis, Nebraska, New Britain, New Orleans, North Texas, Ontario, Oregon, Philadelphia, Pittsburgh, Providence, Rochester, St. Louis, St. Paul, San Francisco, Savannah, Syracuse, Toledo, Tri-Cities, Utah, Virginia, Washington, Waterbury, Western Massachusetts, and Worcester. Each delegate was called upon to present a brief report from his Section. The delegates were addressed by Messrs. Erik Oberg and Geo. A. Orrok, Chairmen of the Finance and Publication Committees, respectively, and by L. W. Wallace, Executive Secretary of the Federated American Engineering Societies. The Council met with the delegates at luncheon at noon on Monday. A more complete account of the transactions of the Council and the deliberations of the conference of Local Sections' Delegates appeared in the December 7 and 22 issues of *A.S.M.E. News*.

Business Meeting

On Tuesday afternoon, December 4, the annual business session of the Society was held. The important action was the presen-

tation of an amendment to the Constitution by which dues for membership in each grade shall be as follows: Member, \$20; Associate, \$20; Associate-Member, \$20; Junior for the first six years of his membership as Junior, \$10 and thereafter \$20. By vote of the meeting this amendment was referred to the membership to be acted upon by letter ballot, according to the provisions of the Constitution.

Prof. John Airey, Ann Arbor, Mich., was present to receive in person the award of Life Membership in the Society. Col. C. F. Hirshfeld accepted the Junior Cash prize for S. S. Sanford, Detroit, Mich., and Prof. Frank B. Rowley the First Student Cash Prize for Charles F. Olmstead, Minneapolis, Minn. The Second Student Cash Prize for H. E. Doolittle, San Diego, Cal., will be mailed to him.

The annual report of the Council was presented by Secretary Rice and the following standards read by title: Standards for Transmission Chains and Sprockets, including those on Revised Sprocket Tooth Form, Space and Straddle Cutters for Sprocket Teeth, and Roller Chain Nomenclature; and Standards for Screw Threads for Bolts, Machine Screws, Commercial Tapped Holes, etc.

The following selection of the Nominating Committee by the conference of Local Sections' Delegates was approved:

Wm. R. Webster, Bridgeport, Conn.; R. Sanford Riley, Worcester, Mass., alternate.

Kingsley L. Martin, New York, N. Y.; John H. Lawrence, New York, N. Y., alternate

Charles Loeber, Richmond, Va.; O. P. Hood, Washington, D. C., alternate.

R. G. Nye, Buffalo, N. Y.; James Guthrie, Cleveland, O., alternate.

William M. White, Milwaukee, Wis.; Harry S. Reid, Indianapolis, Ind., alternate.

E. W. Burbank, Dallas, Tex.; H. R. Auerswald, Oklahoma, alternate.

Bruce Lloyd, San Francisco, Cal.; Wynn Meredith, San Francisco, Cal., alternate.

Student Session

Representatives of twenty-eight Student Branches met in conference on Wednesday, December 5. Dr. Hazen G. Tyler, of the Committee on Relations with Colleges presided and short addresses on the work of the Society and the Student Branches were made by President Harrington, President-Elect Low, Dr. Ira N. Hollis, and Secretary Calvin W. Rice. Problems relating to the operation of Student Branches were presented and discussed by those present.

Entertainments and Excursions

A complete program of events for the ladies was featured at this meeting of the Society. The program included visists to Vantine's store, the factory of the Ward Baking Co., the Kirkman Soap Factory, the Brooklyn Navy Yard, Good Housekeeping Institute, the Colgate Factory, Aeolian Hall, and broadcasting station WJZ. An especially notable occasion was the visit to the art galleries of Senator William A. Clark. The Women's Auxiliary held a benefit card party on Tuesday evening.

The presidential reception, following the presidential address on Monday evening, was the usual enjoyable occasion. The informal dinner and smoker on Tuesday evening was well attended and gave the desirable opportunity for the members of the Society to get together. On Wednesday afternoon the ladies held a reception and served tea. The dinner dance Thursday night was a success from every point of view.

The technical excursions for the members included visits to the plants of the American Machine and Foundry Company, Brooklyn; Wright Aeronautical Corpn., Paterson, N. J.; E. W. Bliss Company, Brooklyn; Durant Motor Co., N. Elizabeth, N. J., and the Tidewater Oil Co., Bayonne, N. J.

Joint Session With American Society of Refrigerating Engineers

W. S. SHIPLEY, President of the A.S.R.E., presided at the joint session with the A.S.R.E. which was held on Tuesday morning, December 4. The first paper, by W. H. McAdams[1], and T. H. Frost,[1] treated the subject of Heat Transfer of Fluids Flowing Inside Pipes. This paper, which was discussed by W. R. Herrod and Gardner T. Voorhees, will appear in *Refrigerating Engineering*, the Journal of the A.S.R.E. The Economical Thickness of Insulation in Refrigerator Cars was treated in a paper by A. J. Wood[2] and Philip X. Rice.[3] This paper was discussed by George A. Nicol, Jr., P. Nicholls, Charles H. Herter, Willis H. Carrier, F. E. Mathews, W. Spraragen, Harry Harrison, F. P. Anderson, and E. F. Mueller. It will appear in abstract with the discussion in a later issue of Mechanical Engineering.

[1] Assoc. Prof. Chemical Engineering, Massachusetts Institute of Technology

Textile Session

THE Textile Session Tuesday morning, December 4, was presided over by Charles R. Main, member of the Executive Committee of the Textile Division under whose auspices the program was arranged.

Two papers were presented: The Organization and Construction of Woolen Mills, by A. W. Benoit,[4] and A Steam-Loss Prevention Plan Operating in a Textile-Finishing Plant, by H. M. Burke.[5] Warren B. Lewis, James W. Cox, A. A. Adler, L. H. Stark, George H. Perkins, Willard H. MacGregor, B. M. Bates, R. Longfield, G. C. Brown, Horace G. Killam, and Charles Bigelow entered the discussion.

Abstracts of the papers and discussion will be presented in later issues of Mechanical Engineering.

Fluid Meters Session

THE open meeting of the Special Research Committee on Fluid Meters scheduled for Tuesday morning, December 4, was attended by more than 75 members of the Society interested in the work of this Committee. This meeting was called primarily for a discussion of Part 2 of the Committee's report in which the characteristics of the various types of flow meters now on the market are fully discussed. Each of the nineteen meters dealt with is treated under the following heads: (*a*) Type and primary device; (*b*) description; (*c*) range of use; (*d*) advantages; (*e*) possibilities of error; (*f*) tests and precision. Prior to the meeting galley proofs of this material were generally circulated to those known to be interested, and a lively three-hour discussion took place at the meeting. The Committee will now revise the material presented at this meeting and present it for final review during the Spring Meeting.

A limited number of advance proofs of the final draft of Part 1 had been circulated to the members of the Committee, and this part was approved for publication with slight changes.

General Session

ROBERT SIBLEY, Vice-President of the Society, presided at the General Session held Tuesday morning, December 4. The paper by S. Timoshenko[6] on Bending and Torsion of Multi-Throw Crankshafts on Many Supports was presented by title. H. A. S. Howarth[7] presented a paper giving a Graphical Study of Journal Lubrication, which was discussed by Daniel Barnard, E. P. Murfree, G. H. Marx, W. E. Symons, James A. Hall, W. T. Magruder, and J. M. Lessells. An abstract of Mr. Howarth's paper and discussion will appear in a future issue of Mechanical Engineering. A paper describing Stress Distribution in Rotating Gear pinions as Determined by the Photoelastic Method was presented by A. L. Kimball, Jr.,[8] who assisted Paul Heymans[9]

[1] Instructor in Chemical Engineering, Massachusetts Institute of Technology.

[2] Prof. and Head of Dept. of Mech. Eng., Pennsylvania State College. Mem. A.S.M.E.

[3] Elec. Engr., Miller Train Control Corp., Danville, Ill.

[4] Textile Engineer, Chas. T. Main, Boston, Mass. Mem. A.S.M.E.

[5] Plant Engineer, Mt. Hope Finishing Co., North Dighton, Mass. Mem. A.S.M.E.

[6] Research Dept. Westinghouse Electric and Manufacturing Co., E. Pittsburgh, Pa.

[7] Genl. Mgr. and Chief Engr., Kingsbury Machine Works, Frankford, Philadelphia, Pa. Mem. A.S.M.E.

[8] Research Laboratory, General Elec. Co., Schenectady, N. Y.

[9] Research Associate, Mass. Inst. Tech., Cambridge, Mass. Mem. A.S.M.E.

in its preparation. S. Timoshenko, E. O. Waters, G. M. Eaton, J. H. Shepherd, R. Eksergian, C. B. Hamilton, F. A. Haughton, J. A. Hall and J. L. Williamson contributed to the discussion, which will appear with the paper in abstract form in a future issue of MECHANICAL ENGINEERING.

Power Test Codes Public Hearing

THE public hearing on the Test Codes for Boilers and Locomotives on Tuesday afternoon, December 4, was very well attended. Edwards R. Fish, Chairman of the Committee which prepared the Test Code for Boilers, presided. In the interesting discussion of these proposed test codes, most of the time was spent on the Code for Steam Boilers and Auxiliary Apparatus. The Individual Committees which drafted these two test codes will now examine the reporter's record of the public hearing, together with all written discussion which they now have or may receive in the near future and will prepare a finally revised draft of their codes for transmission to the Main Committee at its next meeting in March.

Coal-Storage Session

THE program for the Coal Storage Session was the joint product of the Fuels and Materials Handling Divisions. W. L. Abbott, Chairman of the F.A.E.S. Committee on Coal Storage, presided. The first paper, by O. P. Hood,[1] on the Factors in the Spontaneous Combustion of Coal, appeared in the December issue of MECHANICAL ENGINEERING. His presentation was followed by that of F. G. Tryon[2] who, with W. F. McKenney,[3] dealt with the Economic Phases of Coal Storage. Coal-Storage Systems, a paper by H. E. Birch[4] and H. V. Coes[5] was presented by Mr. Coes. Discussion was opened by J. E. Davenport, who was followed by C. G. Spencer, Perley F. Walker, Geo. A. Orrok, John W. Lieb, W. E. Symons, Charles R. Richards, Robert Kleinschmidt, H. B. Chapman, A. J. German, A. A. Adler, N. T. Lownes, N. E. Funk, Charles Bigelow, W. G. Carlton, N. C. Johnson, and E. N. Trump. The papers by Messrs. Tryon and McKenney and Birch and Coes will appear in abstract form in a later issue of MECHANICAL ENGINEERING.

Session on Modern Subway Cars

THE Railroad Division sponsored the Session on Modern Subway Cars which convened on Wednesday morning, December 5. James Partington, Chairman of the Division, introduced E. B. Katte as presiding officer for the session. After the presentation by Selby Haar[6] of his paper entitled Modern Subway Cars and Their Operation, the meeting was thrown open to discussion, those participating being F. M. Brinkerhoff, Joseph C. McCune, F. W. Butt, H. L. Andrews, George L. Fowler, J. H. Davis, Thomas Millaney, G. J. Ray, W. C. Sanders, H. Goldmark, Van Ness Delamater, and C. W. Squier. After the meeting written discussion was received from J. Vipond Davies, who reviewed the history of the design of subway cars. The discussion will be reported in more complete form in a later issue of MECHANICAL ENGINEERING.

Ordnance Session

FRED J. MILLER, Chairman of the Ordnance Division, acted as presiding officer at the Ordnance Session which was held under the auspices of the Ordnance Division on Wednesday morning, December 5. The first paper to be presented was that by Col. W. H. Tschappat,[7] which described New Instruments for Physical Measurement. This paper appeared in the December issue of MECHANICAL ENGINEERING. He was followed by Capt. H. W. Churchill,[8] who related Some of the Production Problems in the War Department's Preparedness Program. The discussion on Capt. Churchill's paper was led by Brig. Gen. C. L.'H. Ruggles, Assistant Chief of Ordnance, and was participated in by representatives of thirty manufacturing firms who had been engaged in the manufacture of ordnance during the war. The questions propounded in the discussion will be abstracted and submitted to the War Department, which will prepare a reply for publication in a later issue of MECHANICAL ENGINEERING.

[1] Chief Mechanical Engineer, U. S. Bureau of Mines, Washington, D C. Mem. A.S M.E.
[2] Division of Mineral Resources, U. S. Geological Survey, Washington, D. C.
[3] U. S. Geological Survey, Washington, D. C.
[4] Sales Manager, R. H. Beaumont Co., Philadelphia, Pa. Mem. A.S.M.E.
[5] Manager, Ford, Bacon & Davis, Philadelphia, Pa. Mem. A.S.M.E.
[6] Electrical and Mechanical Engineer, New York. Mem. A.S.M.E.
[7] Aberdeen Proving Ground, Aberdeen, Md.
[8] Executive Assistant, N. Y. District Ordnance Office, New York.

Steam Table Research

THE remarkable progress of the research in the properties of steam on which new steam tables will be based was told at the Session on Steam Table Research held Wednesday afternoon, December 5. Dr. Arthur M. Greene, Jr., member of the Executive Committee of the Steam Table Fund, presided and introduced Geo. A. Orrok, Chairman of the Executive Committee, who gave a brief report of the administration of the fund. Dr. Harvey N. Davis, in charge of the Steam Research at Harvard, then summed up the results already obtained. He was followed by F. G. Keyes and R. Kleinschmidt, who are engaged in the steam research work at Massachusetts Institute of Technology and Harvard University. N. S. Osborne, who is doing part of the research work at the Bureau of Standards, then told of the plans being prepared at the Bureau and presented a paper on the Calorimetric Method of Surveying the Behavior of Steam. Mr. Osborne's paper and the progress reports will appear in a future issue of MECHANICAL ENGINEERING.

Session on Education and Training for the Industries

THE Committee on Education and Training for the Industries invited a large number of manufacturing executives to attend the Conference on Education and Training for the Industries, which was held Wednesday afternoon, December 5. Fred R. Low, President-elect of the Society, presided at the session, which was opened w th an introductory statement from Dr. Ira N. Hollis,[1] who told of the plans of the Committee to collect information as to the present procedures in educating and training men in the industries. Dean R. L. Sackett[2] then made a brief statement concerning Industrial Education Abroad, after which the meeting was thrown open for general discussion. The Committee was greatly encouraged by the interest shown in the discussion and by the large attendance which overflowed the N.E.L.A. board room in which the conference was held. Dean Sackett's paper, together with a more complete account of the proceedings of the meeting, will appear in a later issue of MECHANICAL ENGINEERING.

Steam Power Session

THE session with the largest attendance and greatest sustained interest was that held by the Power Division on Thursday morning, December 6. There were over seven hundred in attendance during the morning and a large number remained through the afternoon to participate in the discussion. Nevin E. Funk, Chairman-elect of the Power Division, presided over the interesting program.

Papers presented were Boiler-Plant Economics, by N. E. Funk[3] and F. C. Ralston;[4] Boiler Test Results with Preheated Air, Colfax Station, Duquesne Light Company, by C. W. E. Clarke;[5] The Margins of Possible Improvement in the Central-Station Steam Plant, by Ernest L. Robinson;[6] Economy Characteristics of Stage Feedwater Heating by Extraction, by E. H. Brown[7] and M. K. Drewry;[8] Reheating in Central Stations, by W. J. Wohlenberg;[9]

[1] President, Worcester Polytechnic Institute. Past-President A.S.M.E.
[2] Dean of Engineering, Pennsylvania State College. Mem. A.S.M.E.
[3] Philadelphia Elec. Co., Philadelphia, Pa. Mem. A.S.M.E.
[4] Philadelphia Electric Co., Philadelphia, Pa.
[5] Power Engr., Dwight P. Robinson & Co., New York. Mem. A.S.M.E.
[6] General Electric Co., Schenectady, N. Y.
[7] Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.
[8] Steam Turbine Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis
[9] Asst. Prof. Mechanical Engineering, S S S. Yale University. Assoc-Mem. A.S.M.E.

and High Pressure, Reheating, and Regenerating for Steam Power Plants, by C. F. Hirshfeld[1] and F. O. Ellenwood.[2] A large volume of written discussion was submitted by A. G. Christie, R. Sanford Riley, Leo Loeb, L. Helander, Frank S. Clark, B. N. Broido, A. S. Moss, William Keenan, A. A. Adler, F. Hodgkinson, J. H. Lawrence, H. C. Heaton, Vern E. Alden, Geo. A. Orrok, J. N. Landis, Douglas K. Warner and W. B. Flanders. There was also a large amount of oral discussion and questioning from the floor during the session. Mr. Robinson's paper appeared on pages 685–690 of the December issue of MECHANICAL ENGINEERING; the others will appear in future issues, accompanied by brief accounts of the discussion.

Machine Shop Practice Session

TWO topics were discussed at the Machine Shop Practice Session Thursday morning, December 6, which was presided over by F. O. Hoagland, Chairman of the Division. The subject of Pressed-Metal Engineering was treated by Douglas P. Cook,[3] who emphasized the importance of the pressed-metal industry, explained the diversity and complexity of pressed-metal processes, and pointed out the lack of engineering standards and information which result in erroneous designs and unwise specifications. He concluded by showing a number of slides illustrating the replacement by pressed metal of parts formerly made from castings or forgings. In each case Mr. Cook gave actual figures of savings in weight, production time, and cost by the use of pressed metal. He also showed a motion picture of the various steps taken in producing one component of the telephone by the pressed-metal process.

The second paper on this subject was given by W. W. Galbreath,[4] who was assisted in its preparation by John R. Winter.[5] This paper appears in this issue of MECHANICAL ENGINEERING. The discussion of pressed metal emphasized the importance of more accurate information about the performance of metal in the press. The possibilities of the still further expansion of the industry were also emphasized.

The second topic of the meeting was research on cutting and forming metals. The basis for the discussion was the Progress Report prepared by the Special Research Committee on this subject. B. H. Blood, Chairman of the Special Research Committee, presented the report which was fully discussed. The complete report of the committee appears elsewhere in this issue of MECHANICAL ENGINEERING and is followed by a brief abstract of the discussion.

Aeronautic Session

THE Aeronautic Session, held under the auspices of the Aeronautic Division on Thursday morning, December 6, was presided over by E. P. Warner, Chairman of the Division. Corrosion of Aluminum Alloys was discussed in two papers, one by D. Basch[6] and M. F. Sayre,[7] presented by Mr. Basch, and one by Henry A. Gardner,[8] presented by the presiding officer. These two papers were discussed by Robert J. Anderson, T. S. Fuller, J. B. Johnson, E. B. Pannell, Archibald Black, F. B. Coyle, E. M. Hewlett, A. J. Lyon, L. Ochtman, Jr., and Ralph Goetzenberger. The paper by Messrs. Basch and Sayre appeared in the December issue of MECHANICAL ENGINEERING. Dr. Gardner's paper, with an abstract of the discussion, will appear in a later issue. Archibald Black[9] and D. R. Black[10] contributed a paper on The Commercial Possibilities of the Airplane which was presented by Archibald Black.

[1] Chief, Research Dept., Detroit Edison Co., Detroit, Mich. Mem. A.S.M.E.
[2] Professor, Cornell University. Mem. A.S.M.E.
[3] President, Boston Pressed Metal Co., Worcester, Mass.
[4] President, The Youngstown Pressed Steel Co., Warren, Ohio.
[5] General Superintendent, The Youngstown Pressed Steel Co., Warren, Ohio.
[6] Research Engr. Gen. Elec. Co., Schenectady, N. Y.
[7] Asst. Prof. Applied Mechanics, Union College. Mem. A.S.M.E.
[8] Henry A. Gardner Laboratory, Washington, D. C.
[9] Consulting Aeronautical Engineer, Garden City, L. I. Mem. A.S.M.E.
[10] Consulting Aeronautical Engineer, Garden City, L. I. Assoc-Mem. A.S.M.E.

This paper was discussed by L. B. Lent, Wm. B. Stout, H. M. Crane, Grover Loening, H. A. Bruno, E. H. Steef, R. R. Blythe, and Harold P. Clyde. The paper on Night-Flying Equipment and Operation by Lieuts. H. R. Harris[1] and D. L. Brunner[1] was presented by Lieutenant Brunner. These last two papers will appear in later issues of MECHANICAL ENGINEERING.

Management Session

THE Management Session on Thursday afternoon, December 6, was devoted to a Symposium on the relationship of mechanical engineering to management in three industries, Robert T. Kent[2] discussing the metal-working trades, W. L. Churchill[3] the woodworking industries, and E. H. McKitterick[4] the textile industry. Irving A. Berndt, member of the Executive Committee of the Management Division, presided. Discussions of the three papers were submitted by A. F. Brewer, M. E. Popkin, William P. Hopkins, W. L. Conrad, E. D. Beals, Hugo Diemer, J. P. Jordan, A. J. McCarte and Dwight B. Merrick. There was also a large amount of oral discussion from the floor. Mr. Churchill's paper appeared on pages 692–694 of the December issue of MECHANICAL ENGINEERING. The papers by Messrs. Kent and McKitterick will appear in later issues together with the discussion presented at the session.

At the close of the session a report was presented by the Committee on Elimination of Fatigue of the Society of Industrial Engineers. This report, prepared by George H. Shepherd, Chairman of the Committee, emphasized the lack of quantitative data on fatigue effects and requested the coöperation of all members of the A.S.M.E. in bringing the matter of elimination of fatigue to the attention of educational authorities, especially those concerned in vocational fields, in the hope of bringing about a better state of general knowledge on this elsewhere important subject. Fatigue due to improper seating, muscular fatigue, and eye fatigue are now the subjects of research.

Oil Engine Session

ELMER A. SPERRY, Chairman of the Gas Power Division, presided over the Oil Engine Session which was held on Thursday afternoon, December 6. A paper on The Solid-Injection Oil Engine written by H. F. Shepherd[5] was presented by Louis R. Ford. L. A. Hadley and Louis Illmer submitted written discussions. L. H. Morrison[6] read a paper on The Economic Status of the Diesel Engine, which was discussed in writing by J. B. Frauenfelder, S. A. Hadley, R. C. Burrus and C. L. Ruegg. The discussion from the floor was voluminous. The papers presented at this session will appear with the discussion in later issues of MECHANICAL ENGINEERING.

Water-Measurement Session

WILLIAM M. WHITE presided over the Session on Water Measurement which was held on Thursday afternoon, December 6, under the auspices of the Power Division. Following the presentation by title of a paper on Flow of Water in Short Pipes, written by O. W. Boston,[7] two methods of measuring water were presented. The Salt Velocity Method was described by Charles M. Allen[8] who presented a paper on the subject jointly with Edwin A. Taylor,[9] and the Gibson Method was given by Norman R. Gibson.[10] An abridgment of the latter paper appeared in the December issue of MECHANICAL ENGINEERING. An abstract of the paper on the salt velocity method appears in this issue, fol-

[1] Air Service, McCook Field, Dayton, Ohio.
[2] Consulting Management Engr., Montclair, N. J. Mem. A.S.M.E.
[3] Industrial Engineering Service, New York. Mem. A.S.M.E.
[4] Lockwood, Greene & Co., Boston, Mass.
[5] Consulting Engr. Foos Eng. Co., Springfield, Ohio.
[6] Asst. Editor *Power*, New York. Assoc-Mem. A.S.M.E.
[7] Acting Director Engineering Shops, University of Michigan. Assoc-Mem. A.S.M.E.
[8] Professor Hydraulic Engineering, Worcester Polytechnic Institute. Mem. A.S.M.E.
[9] Hydraulic Engineer, Worcester, Mass.
[10] Consulting Engineer, Niagara Falls, N. Y.

lowed by a brief abstract of the discussion on the papers on water measurement.

National Exposition of Power and Mechanical Engineering

OVER 62,000 visitors attended the Second National Exposition of Power and Mechanical Engineering which opened at the Grand Central Palace, New York, at 2:00 p.m. on Monday, December 3, and continued daily through the week. After the first day the Exposition was opened from noon until 10:00 p.m. It comprised over 260 exhibits of all classes of power-plant apparatus, with a large representation of material-handling devices, power-transmission apparatus, and a sprinkling of metal-working tools. The exhibits filled the main and mezzanine floors of the Grand Central Palace. Comments of both visitors and exhibitors were enthusiastic as to the interest and value of such an exposition, especially as it was held parallel with the Annual Meeting of the A.S.M.E. and thus gave members not only an excellent opportunity to view the exhibits but at the same time a chance to enjoy the sessions.

Interconnection of Power Systems

(Continued from page 12)

among the great power companies of the country is the extension of their distribution systems over vast territories and of the interconnection between these systems. Those who have not followed in detail the development of power transmission during the past twenty years are perhaps not familiar with how far that tendency has already gone. We hear a great deal nowadays about superpower, and I am afraid that that word is being overworked and is leading the public to believe that some new and mysterious enterprise is coming along the road which is going to cut their power bills in two. That, of course, is not the fact.

Some twenty years ago the Niagara Falls Power Company was engaged in the distribution of 200,000 hp. over a territory of some 10,000 square miles. That had elements of superpower in it, itself. Ten years ago, in the state of California, there was a network of transmission which was practically 700 miles from its northerly limit to its southerly limit. At the present time the entire states of North and South Carolina are connected solidly with a gridiron of lines operated by many water powers and some steam reserve.

Within recent months, I am informed, certain transmission links have been completed, so that power can be theoretically transmitted from St. Paul to Chicago, from Chicago to Indianapolis, Indianapolis to Cincinnati, Cincinnati to Louisville, Louisville to Nashville, Nashville to Birmingham, and Birmingham to Atlanta, through the systems of the Northern States Power Company, the Chicago Edison, the Ohio Power, the Kentucky and West Virginia Power Company, the Kentucky Utilities, the Tennessee Power, the Tennessee Eastern Power, the Alabama Power, and the Georgia Railway and Power Company. That is an enormous step in advance in the line of superpower which is already today in existence.

I do not believe, however, that this superpower idea is going to materially reduce the cost of power. I do not see that it is working that way in any respect. It is merely increasing the available supply of power and making it possible for the isolated manufacturer who now operates an efficient plant to connect his works to the network and derive the very great benefit which will result from that.

But the greatest and most important relation which this extension and interconnection of lines has to water power is in making certain water powers available at all. I think it is a great fallacy, this discussion as to which is the cheaper, steam or water power. It befogs the issue and is not the question before us at all. Water power, to be made available, at least in the eastern states of this country, must, I think, in almost every case, be developed and operated in conjunction with a steam plant, and the question before us is: How much of the stream flow of any given river is justified in development, and how much of the proportion must be carried by steam?

At this point Mr. Buck displayed lantern slides showing the hydrographic records of the Tennessee River, the New River, the Hudson River, the Cumberland River, the Feather River, and a river in Japan under minimum- and maximum-flow conditions. He pointed out the necessity for a combination of steam plants with the water power available in order to bring the primary power to a reasonable amount in eastern rivers which flow in territories that have been built up and are occupied by railroads, highways, and other obstructions so that storage is difficult to develop at a reasonable price. For the Feather River, a western stream, ample storage facilities were available, so that steam was not required in the power development. The Japanese situation was such that the peak load was carried by the water power and a steam plant was operated as a base-load plant at practically 100 per cent load factor.

Mr. Buck concluded his remarks with a plea to those who are interested in water-power development to devote their efforts to the question of the proper combination of steam and water power in order to justify the development of the latter.

General Discussion at Hydroelectric Session

IN DISCUSSION from the floor, William M. White[1] quoted an English statesman who said in an open Parliament meeting a few years ago, that the reason why the American manufacturer could compete successfully in the markets of the world and yet pay twice the rate of wage to the American workman that was paid to the British workman, was because each American workman directed twice the horsepower per man that the individual British workman did. Mr. White found that this ratio of available power to wage rate applied also in Japan. He pointed out the small amount of supervision necessary in the operation of hydroelectric plants and compared it with the effort to produce a like amount of power from coal, which requires the uninterrupted service of 1500 men to mine, break, hoist, sort, load, transport, unload, store, rehandle, and fire under the boilers a sufficient amount of coal to produce 40,000 hp., where a hydroelectric plant of the same capacity requires but two men. Mr. White emphasized the fact that the utilizing of fifteen hundred men in this way, employing the already overloaded railways for transporting coal, was a great economic question.

J. P. J. Williams[2] emphasized the interests of the consumer in securing power at the lowest possible rate. He outlined the possibilities of economy in producing hydroelectric power through public ownership and public development and stated that three cents per kilowatt-hour is the price at which the Hydroelectric Power Commission of Ontario is producing power. He stressed the interest of the farmer in cheap power and read the resolutions of the Public Ownership League which advocate complete development and utilization of electric power in the interest of general welfare upon three principles: engineering efficiency, coördination in natural resources with electric utilization, and the interconnection, coördination, and combined operation of a large number of plants or systems of plants.

T. Kennard Thomson[3] quoted the *Financial Post* of Toronto in a statement that the privately operated companies in the province of Quebec are selling power at a much lower rate than the publicly owned companies of the province of Ontario. Mr. Thomson also called attention to the fact that developing the eight million horsepower from the Niagara and St. Lawrence Rivers during the next ten or fifteen years would only take care of the increased demand for coal or for power supplied by coal in the state of New York alone.

In his closing remarks Chairman Stillwell emphasized the fact that the power load on the farm has two very high peaks during twenty-four hours. He also stressed the important need of standardizing voltages and frequencies to permit the interconnection of power systems with the best economy possible to the art.

[1] Chief Engr. Hydraulic Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.
[2] Civil Eng. Dept., Cooper Union, New York. Mem. A.S.C.E.
[3] Consulting Engineer, New York. Mem A.S M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

High Pressures and High Superheats in Modern Steam-Power-Plant Practice

By W. G. NOACK

THAT the economy of steam generation may be improved by the use of higher pressures and temperatures may be considered as being established. The question now is whether and to what extent the present state of turbine development permits an increase of initial temperatures and pressures. That turbine operation is materially affected by the initial steam conditions, there is no doubt. Thus, for example, an increase in steam pressure means a reduction of the specific steam volume, and thus for the same pressure difference in the first stage as used today means a reduction in size of the turbine for a given output. There are also other ways in which an increase of pressure and temperature of steam affects turbine design and operation.

In order to obtain, at least in the first wheel, the most favorable steam conditions possible, an effort was made when dealing with high live-steam pressures and high superheat temperatures to utilize very large drops in the first stage. This, of course, resulted in a rapid lowering of temperature and pressure, but the high exit velocity c of steam from the nozzles brought about a much worse ratio of velocities u/c and hence a worse wheel efficiency, even when the peripheral velocity of the wheel u could not be further increased.

It would appear, therefore, that even if this method of operation were practicable when the pressures were not extremely high, it fails to work at pressures in excess of 50 atmos. combined with very high superheats, and when such pressures and temperatures are used

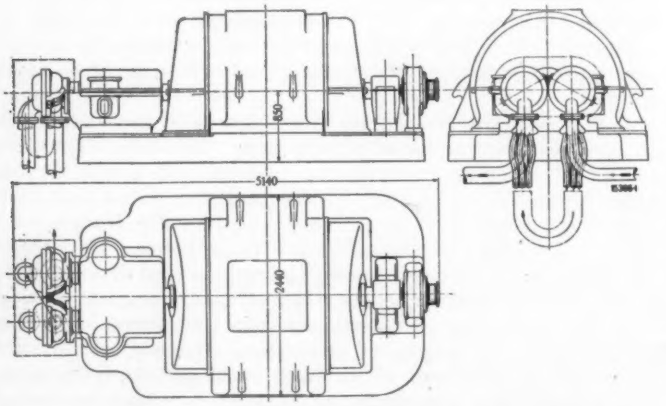


FIG. 1 3000-KW. HIGH-PRESSURE SERIES TURBINE. GENERATOR SPEED 3000 R.P.M.

the present turbine design has to be abandoned and a new type developed, the changes affecting, in particular, that part of the turbine which deals with high-pressure and highly superheated steam. This part has to be redesigned in order to take care of the new steam conditions, which becomes possible only when the high-pressure and low-pressure parts are separated from each other. It would further appear that the most suitable dividing point is the steam condition which permits the second half of the turbine to be designed as a perfectly normal type of ordinary steam turbine.

Should a high-pressure, high-superheat turbine be arranged in accordance with the viewpoint expressed above, it becomes possible to operate the machine with any desired pressure and the highest temperature available so long as the materials used in turbine construction will withstand it. It then becomes possible to abandon entirely the present gradual process of development and without any danger jump to pressures of the order of 50 and even 100 atmos. (711 to 1422 lb. per sq. in.) and risk using superheat temperatures of 400 to 500 deg. cent. (752 to 932 deg. fahr.).

The Brown-Boveri turbine for high-pressure steam consists therefore of a high-pressure turbine—referred to here as a series turbine—and a low-pressure turbine, which latter is designed in the convential manner for ordinary steam pressures. The series turbine may consist of one or more casings through which the steam flows in series. The steam leaving the last casing at, say, 12 to 20 atmos., goes then into the low-pressure turbine. The name "series turbine" was given to the high-pressure turbine, because, employing an electrical comparison, it is in series with the low-pressure turbine. Fig. 1 shows an example of such a machine. This turbine is rated at 3000 kw. at 100 atmos. initial pressure and 16 to 20 atmos. back pressure. It consists of two casings each con-

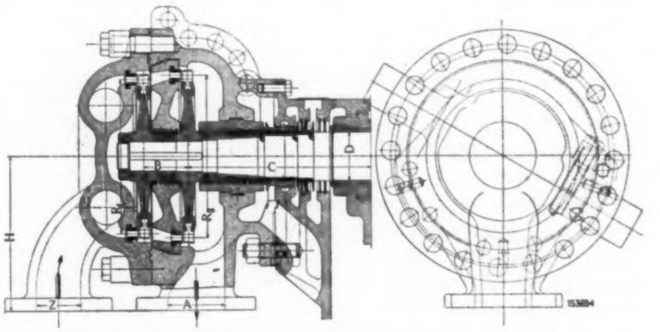


FIG. 2 HIGH-PRESSURE DOUBLE STAGE OF THE FOUR-WHEEL SERIES TURBINE OF 3000 KW. CAPACITY

taining two wheels. Fig. 2 shows a section through the first stage of this 3000-kw. series turbine. It works with an initial pressure of 80 to 100 atmos., the pressure on the first wheel being 60 atmos. and that on the second wheel, 40 atmos. The speed of the wheels is 8000 r.p.m. and the output better than 1500 kw. The feature which immediately attracts attention is the remarkably small size of the parts as compared with the powerful output. The small diameter of the wheels permits a practically complete loading of the available blade heights. Also the small size of the wheels reduces the wheel friction and fan losses to a negligibly small amount. The peripheral velocities, especially in the first stages, which operate with high-temperature steam, are low, and this reduces the wheel stress due to centrifugal forces to a minimum. In fact, the stresses in the first wheels of these high-pressure turbines are but from one-third to one-quarter those in the disks of modern high-output machines, the result of which is that the materials as regards safety against rupture are better off in the high-superheat turbine than in the conventional turbine, and this notwithstanding their loss of strength due to the higher temperatures. By permitting very high temperatures in wheels as the result of employing lower peripheral velocities, it has become possible to keep the pressure and temperature drop in each stage low and to give them such magnitudes as to secure the most favorable ratio u/c and the highest wheel efficiency.

The employment of the small-diameter wheel makes it necessary to use high rotative velocities. The series turbine is therefore practically always equipped with a gear which reduces the speed of the turbine wheels to that of the generator. The small weight of the disks and the usual subdivision of the series turbine into sev-

eral casings each of which contains not more than two wheels, makes it possible to arrange the wheels in overhung formation and to make the connection direct to the pinion shaft of the reduction gear.

Because of the arrangement of the wheels adopted in this type of turbine a stuffing box at one side of the housing is eliminated; on the other side the usual labyrinth type of packing is employed, and a certain amount of steam proportionate to the high pressure is allowed to escape through the bearing stuffing box. This bearing-leakage steam is delivered to the condensate where its heat is recovered. Water cooling is provided between the stuffing box and the first bearing, which takes care of the conduction and radiation from the turbine housing and keeps them away from the bearing and transmission gear. This water-cooling arrangement consists of a bushing set close about the shaft and provided with a

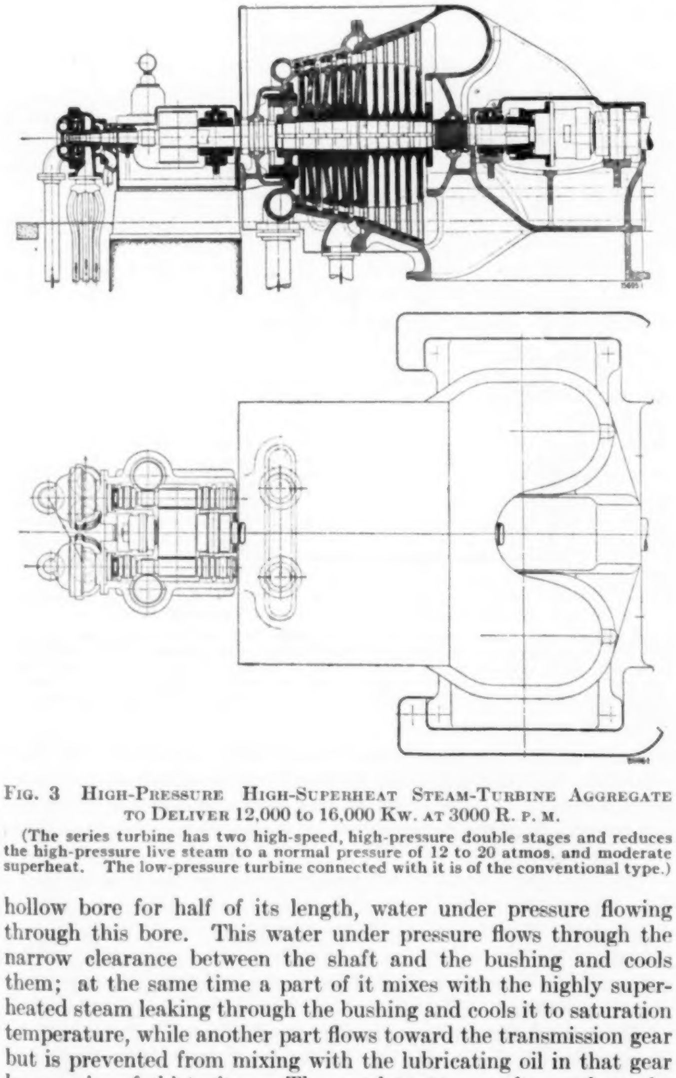


FIG. 3 HIGH-PRESSURE HIGH-SUPERHEAT STEAM-TURBINE AGGREGATE TO DELIVER 12,000 TO 16,000 KW. AT 3000 R. P. M.

(The series turbine has two high-speed, high-pressure double stages and reduces the high-pressure live steam to a normal pressure of 12 to 20 atmos. and moderate superheat. The low-pressure turbine connected with it is of the conventional type.)

hollow bore for half of its length, water under pressure flowing through this bore. This water under pressure flows through the narrow clearance between the shaft and the bushing and cools them; at the same time a part of it mixes with the highly superheated steam leaking through the bushing and cools it to saturation temperature, while another part flows toward the transmission gear but is prevented from mixing with the lubricating oil in that gear by a series of skirt rings. The condensate may be used as the cooling liquid in this arrangement. The clearance of the cooling bushing need be only a little more than the usual bearing clearance and it is advisable to keep both clearances as small as possible in order to reduce the clearance in the labyrinth packing. The shaft is of the rigid type and it may be assumed that the centering action produced by the pressure of the cooling water on the shaft from all sides raises the critical speed of the shaft considerably and consequently reduces the wear in the labyrinth-packing parts. Because one shaft end is eliminated there arise as a result of one-sided action of the steam pressure forces acting axially on the shaft, but these can be partly or fully equalized by the forces acting peripherally on the pinions, these in their turn being produced by a proper inclination of the teeth. The pinions are equipped with a thrust bearing acting in one direction only and the wheel has similar bearings also.

If the outputs of the two turbines meshing with the same wheel or their peripheral forces on the wheel are equal in magnitude the journal of the transmission gear wheel is practically free of all bending moments. This makes it possible also for this wheel to be overhung on its shaft and, in fact, it may be fastened directly on to the shaft end of the generator, thus making a separate coupling and separate bearing unnecessary. In such a case the generator bearing would be built into the casing of the gear drive, and only one generator bearing proper provided in the same manner as is done with conventional turbines. If the temperature and pressure heads utilized in the series turbine are such as to require more than two casings, then four casings are used, arranged symmetrically on both ends of the generator shaft. In that case both bearings are built into the gear-drive castings and both ends of the generator shaft equipped with reduction-gear drives. The axial thrust due to the peripheral forces of the reduction-gear wheels can then be completely equalized, as, for example, by giving the teeth of the two wheels different inclinations.

The series turbine may be coupled with the low-pressure turbine instead of a generator. In such a case the reduction gear of the series turbine is either equipped with a coupling which connects with the extension of the shaft end of the low-pressure turbine, or the reduction-gear wheel may be set overhung on the shaft end of the turbine. Fig. 3 shows such an arrangement. The series turbine always works with one or more low-pressure turbines and the coupling may be effected either mechanically or electrically by driving the generators in parallel and delivering the current to the same system.

Obviously, the series turbine working with steam of very high pressure and high superheat can be built only out of suitable materials. For the casings, castings preferably of electric steel should be used; stuffing-box sleeves should be made of chrome-nickel steel or similar high-strength non-rusting steel; the softer parts of monel metal, the blades and wheels of high-strength heat-resisting steels. The pinions and shafts should be of chrome-nickel steel. The piping connecting the various parts should be made as a bundle of pipes consisting of a large number of thin-walled steel tubes, this arrangement being recommended in order to prevent stresses in the casings produced by thermal stresses and expansion of the piping.

In plants where the turbine is to be operated on highly superheated steam it may prove of advantage to raise steam to its highest temperature in a separately fired superheater, and to place the usual regulating and shut-off devices *ahead* of the superheater so that these devices will deal only with moderately superheated steam, and further, in order that the superheater shall work with less pressure when the demand for the steam falls off. If this is done it will be absolutely necessary to provide between the regular valve gear and the turbine devices which will control the steam in the superheater and piping and also render harmless any breakdown of the regular valve-gear control. This may be done by employing throttling or blow-off valves set directly into the nozzle passage of the first high-pressure stage. As this throttling arrangement deals only with acceleration of the governing process, it is not necessary to keep it absolutely tight or to have it work in a very precise manner, and this makes it rather less important that these devices are exposed to the action of highly superheated steam and therefore may not work with the same degree of precision as the usual apparatus of a similar character. The blow-off valves, which under certain conditions would let the steam in the superheater escape into the exhaust-steam piping of the series turbine or even into free air, may be set well ahead of the superheater, since it is immaterial in which direction the blow-off steam leaves the superheater.

The auxiliary valve and safety devices are actuated by the same velocity-type governor which actuates the main valve gear and operate either simultaneously with the latter or with a certain lap or lead. The best plan, however, is to control these valves by a governor of their own. Oil under pressure is used for actuating the valve gear in the same way as in the ordinary Brown-Boveri turbines. As a rule, therefore, series turbines designed for operating on highly superheated steam are equipped with two governors, each driven by one of the two pinions. Like all ordinary turbines the series turbine has also a safety governor set on the shaft end of the large reduction-gear wheel. When the safe velocity has been

exceeded this governor operates the quick-acting shut-off valve, and also the blow-off valve where one is provided.

There is not much to say about the low-pressure (which may also be called the "normal-pressure") turbine. As a rule the conventional type of machine may be used for this purpose. Where the series turbine does not drive a governor of its own but is mechanically coupled to the low-pressure turbine, the bearing casing on the valve-gear side of the turbine needs some changes from the standard design, as all the valve gears up to the overload valve may be eliminated on the low-pressure side. As a rule, however, all of these parts of the valve gear on the low-pressure turbine are retained, in order to make it possible to operate this turbine as an independent unit should the high-pressure turbine be removed. This presupposes the fact, of course, that steam of proper low pres-

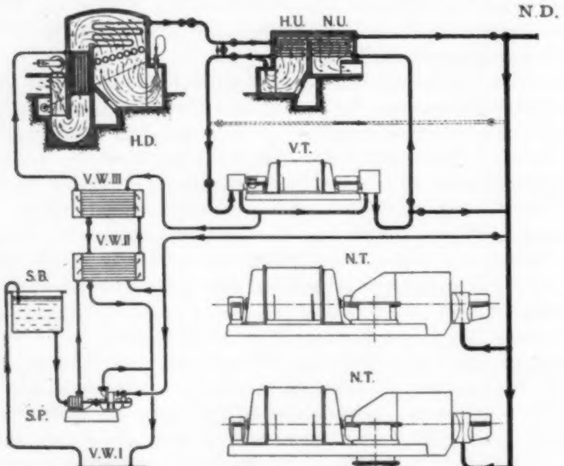


FIG. 4 HIGH-PRESSURE STEAM-TURBINE AGGREGATE JOINTLY OPERATING WITH A CONVENTIONAL-TYPE LOW-PRESSURE TURBINE

(H.U., high-temperature superheater; N.U., intermediate superheater. For other notation see Fig. 5.)

sure is available directly from boilers or that the high-pressure boiler plant is capable of delivering normal-pressure steam after the series turbine has been bypassed. As a rule both conditions are present. Because of the limited ability of high-pressure steam generators to handle rapid and large changes in steam demand, it is recommended that only such combined machines as are subject to small or slowly developing changes of load be driven on high-pressure steam, i.e., those which have mainly to handle the constant load of a central station. For handling peak loads the low-pressure turbines supplied with steam from low-pressure boilers may then be used. This being so, the low-pressure turbines connected with the series turbines may also be fed from these low-pressure boilers, the exhaust steam from the high-pressure series turbine being delivered into the collector pipe of the low-pressure boiler with or without preliminary superheating.

Figures in the original article show the improvements in total efficiency and output which may be obtained without increasing the fuel consumption by simply replacing the low-pressure equipment with one operating at a pressure of 100 atmos. and superheat of 400 and 460 deg. cent. (752 to 860 deg. fahr.). From these curves it would appear that the low-pressure plant working with 12 atmos. abs. of live-steam pressure consumed about 6000 cal. (23,808 B.t.u.) to produce 1 kw-hr. equivalent to 6.25 kg. (13.75 lb.) of steam or 0.85 kg. (1.87 lb.) of coal. When replaced by a series turbine operating at 100 atmos. pressure and 400 deg. (752 deg. fahr.) superheat, the performance was improved by 44.5 per cent and at 460 deg. (860 deg. fahr.) superheat by 49.5 per cent. The total efficiency of the combined machine consisting of a series turbine connected with and feeding to a low-pressure turbine represented an improvement as compared with previous practice of 20.7 or 21.4 per cent.

From the point of safety it should be noted that where the high-pressure aggregate handles the constant base load and the low-pressure turbines the peak load, the main part of the load can be carried even should the high-pressure aggregate be out of business for some reason or other.

Figs. 4 and 5 show the arrangement of plants having series turbines. The difference between the two lies in the difference of provision for feedwater heating. In Fig. 4 the first preheating is effected by exhaust steam from the auxiliary turbine which drives the feed pump, supplemented by leakage steam from the high-pressure-turbine stuffing boxes. The second preheater is fed with exhaust steam from the series turbine, and the third by bleeder steam from the second stage of the series turbine. The condensate from the heating chamber of the preheater is delivered through a pressure-reducing valve into the preheater preceding it. The flue-gas heat not previously utilized serves to preheat the air of combustion, and the high-pressure boiler is fired with pulverized coal. For giving the high-pressure steam its high superheat is used a

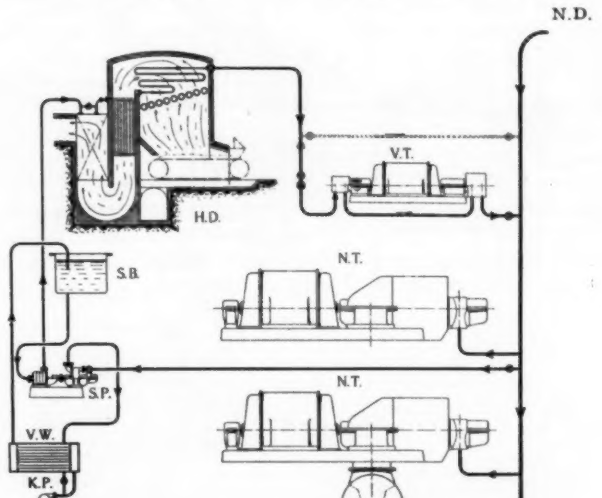


FIG. 5 HIGH-PRESSURE STEAM-TURBINE AGGREGATE JOINTLY OPERATING WITH A CONVENTIONAL-TYPE LOW-PRESSURE TURBINE

(Notation: HD, high-pressure steam generator; ND, low-pressure steam generator, VT, high-pressure series turbine; NT, low-pressure turbine; VW, feedwater preheater using exhaust steam from auxiliary turbine; SP, feedwater pump, SB, feedwater tank, KP, condensate pump; dot in circle, throttling valve; cross in circle, shut-off valve; cross in double circle, regulating valve connected with the governor.)

separate high-temperature superheater with powdered-coal firing of its own, built in a unit with the intermediate superheater used for supplementary superheating of the steam exhausting from the series turbine to the temperature of steam coming from the low-pressure boilers.

The arrangement of Fig. 5 is much simpler, as the high-temperature superheater, the intermediate superheater, and preheater are eliminated. The feedwater is here preheated exclusively by the flue gas. No air preheating is employed and superheating of the high-pressure steam is carried on entirely in the high-pressure steam generator. (*Hochdruck und Hochüberhitzung, Ihre Entwicklung und Anwendung in Dampfkraftbetrieben.* Published by Brown, Boveri & Cie, Baden, Switzerland, June, 1923, 19 pp., 21 figs., *dpA*)

Short Abstracts of the Month

AERONAUTICS

Gliders and Light Planes

THE author considers this subject as another path which may lead to a really successful application of aeronautics to peace purposes. Success in peaceful commercial work is now even in the highest circles becoming recognized as a necessity for success in times of trouble. Furthermore, gliders and light airplanes afford the best possible means of full-scale research from which data can be gathered and ideas stimulated toward the development of com-

mercial aircraft, and it is to commercial aircraft and not to war aircraft that one must look for the real future in the air.

As regards the question whether commercial aircraft can be made to be a real paying proposition, the author answers decidedly in the negative. At the present state of knowledge the best designer in the world cannot make an airplane which is a real paying proposition in the commercial sense.

Coming to the light plane, the author is skeptical about the immediate appearance of large numbers of small sporting machines for one or possibly two people to use in cruising about the countryside.

Up to date the control problem is not sufficiently solved for an airplane to be suitable for the general public to use for their own private touring from place to place. The performance of a new machine is usually as anticipated, but there is not a designer living who can guarantee that his new type of machine will behave in a perfectly normal manner under all circumstances, and even if he could, the normal control is not good enough. Until the problem of airplane control, particularly at low speeds, has reached a more satisfactory solution, there would be so serious a crop of accidents that people would become alarmed and aeronautics would take a setback instead of a step forward.

As regards public trials of light planes, the author, who was closely connected with a competition for prizes offered in England in September, 1923, says that the most valuable result he looks for apart from arousing the public interest is the demonstration of higher aerodynamic efficiencies than have been known up to date—in other words, of better gliding angles. From this he proceeds to a discussion of what is the best gliding angle of a modern airplane. He feels confident that the figure of one in twelve will soon be reached. Some interesting points about the small airplanes are mentioned, in particular one in connection with the climb. There seems to be a singular reluctance on the part of some of these small machines to climb the first 100 ft., the small machines in this respect being quite different from the earliest Wilbur Wright machines. The reason for this lack of ability to rise is not clear. (Col. A. Ogilvie, in *The Journal of the Royal Aeronautical Society*, vol. 27, no. 155, Nov., 1923, original paper, pp. 524–528 and discussion 528–534, *g*)

Requirements of a Man-Propelled Airplane

IN discussing the requirements and limitations of such a machine the author states that as regards the power available it has been found that a man can exert one horsepower for a short time—how long depends on the man. One horsepower is 33,000 ft-lb. per min., or 165 lb. raised 200 ft. per min. A 165-lb. man running up stairs at the rate of 200 ft. per min. exerts one horsepower, which we shall assume as the input.

Regarding propeller thrust, the slower the speed required to fly, the greater the thrust available. One horsepower is 375 mile-pounds per hour, or for example, 18.8 lb. at 20 m.p.h. For a propeller having 80 per cent efficiency this would give 15 lb. thrust.

It is desirable to give a "cycleplane" the largest practicable wing area, both because it permits low speed, thus increasing thrust, and because it allows the use of a low lift coefficient and consequently a high L/D ratio.

The parasite resistance increases as the square of speed, but is small for these low speeds.

As an illustration, consider two machines—one being loaded 1 lb. per sq. ft. of wing area, and the other 0.6 lb. It is permissible to build these machines light, and from preliminary estimates it appears that the weight can be kept within 100 lb., including the propelling mechanism. Assuming the operator to weigh 150 lb., we have 250 lb. total weight.

Next, the author gives a table showing the aerodynamic characteristics of a cycleplane or man-propelled airplane, the available thrust being given in pounds for 1 hp. and 80 per cent efficiency. From this it would appear that all resistances are greater than the available thrusts for a machine loaded 1 lb. per sq. ft. of wing area.

Another table is given for the same characteristics but referring to a machine loaded only 0.6 lb. per sq. ft. per wing area. From this table it appears that at 20 m.p.h. resistance is 13.6 lb. and thrust 15 lb., and that at 17.5 m.p.h. there is still 1 lb. leeway between resistance and thrust.

If a larger wing area were assumed for the same weight the results would be still better, but the machine would be fragile and unmanageable.

Taking 0.6 lb. per sq. ft., 250 lb. requires a wing area of 417 sq. ft., which would give a biplane wing about 6 ft. by 36 ft., or a triplane wing about 5 ft. by 30 ft. However, allowance would have to be made for some loss in efficiency due to biplane or triplane effect.

Careful design would be required to keep down the weight of such a machine, but even so, it should be evident that except as an interesting experiment and as a proof that man-powered flight is possible for a few brief instants, a "cycleplane" or "aviette" would have little practical value. At the same time it seemed interesting to the author to make clear the lower limits in power required to carry a man in flight without a mechanical motor, for this subject is a source of constantly recurring "inventions" which entail expenditures of money and efforts out of all proportion to the results it is reasonable to expect. The data given in the tables accompanying this article, the author believes, should make this fact quite evident. (Matthew B. Sellers in *Aviation*, vol. 15, no. 20, Nov. 12, 1923, pp. 608, *t*)

AIR MACHINERY (See Pumps)

ENGINEERING MATERIALS (See Special Processes)

FOUNDRY (See also Power-Plant Engineering)

Casting-On to Metal in Foundry Work

AN article of a practical character specifying some of the methods used and precautions that have to be taken in doing this kind of work.

As examples the author cites cases of casting-on a short handle rammer or a boss on the center of a rod. A more interesting case is the one where, say, a pump ram has to be coated with brass or bronze; this should be done in two operations, about half an inch of metal altogether being put on. The rod should be cleaned and tinned, care being taken to have the grooves coated with tin, and a flask of sufficient length should be cut out at one end to receive the end of the rod. Two patterns of the proper sizes are rammed up successively, the mold in section when ready for pouring each time appearing as shown in Fig. 1, the metal being allowed to flow

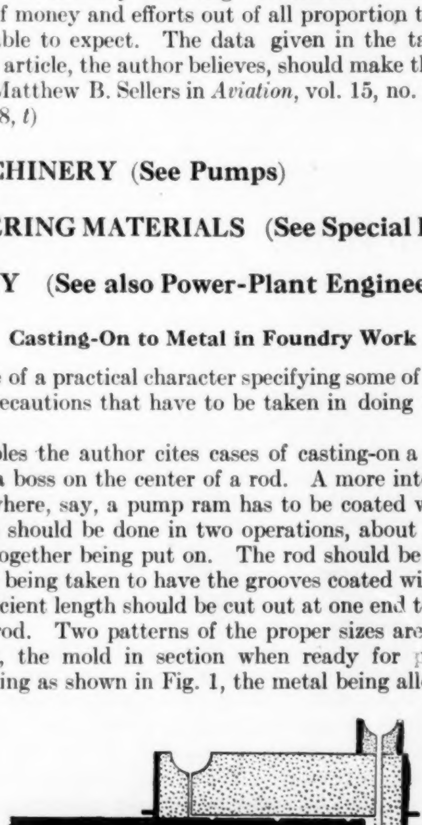


FIG. 1 SECTION SHOWING METHOD OF CASTING-ON LINER TO ROD OF A RAM PUMP

through at each pouring. The first pouring will probably be somewhat porous, which is a matter of small moment, but the second pouring should be sound, as this has to be turned up bright and smooth; the porous first coat of yellow metal affording a better key for the second coating, which has to hold by shrinkage stresses only. Within reasonable limits, the outer coating of metal should be thick to allow of plenty of material to cut away when turning to size, as this permits of the production of a better working surface. (*English Mechanics and the World of Science*, vol. 118, no. 3056, Oct. 19, 1923, pp. 162–163, 4 figs., *p*)

Multiple Electric Welding

IN an address before the National Founders' Association, November 21, Enrique Touceda, consulting engineer of the American Malleable Castings Association, described a new method of handling electric furnaces.

In a large iron and steel foundry in western Pennsylvania two $1^1/_2$- to 3-ton furnaces are mounted upon a revolving platform, by which means the same transformer and set of electrodes can be used for each furnace alternately.

If a cold charge is used, the procedure is to charge both furnaces and, when the metal is ready to tap from the active one, the electrodes are raised, the table revolved and the other furnace placed in position under the electrodes and the melting started coincident with the tapping of the first furnace; that is, no time is lost between melting period, for one furnace is melting while the other is being tapped. Each furnace can be operated independently while the other is undergoing repairs, and the continuous operation of a single substation insures a high load factor, lower power cost, and a saving in electrode consumption.

On the one hand, it is possible in this way to secure better temperature control, more accurate composition, and, in Mr. Touceda's opinion, lower foundry losses to a substantial extent. On the other hand, it is obvious that no troubles can be eliminated that are incident to general molding practice, as no method of melting can do away with losses that arise from weak or wet sand, shifted cores or copes, crushes, cope drops, core blows, incorrect heading or gating, etc.

The original article is illustrated by a series of curves showing comparative power consumption in single and multiple-furnace operation, and which are in favor of the latter. (*The Iron Age*, vol. 112, no. 22, Nov. 29, 1923, pp. 1441–1442, 3 figs., *dp*)

FUELS AND FIRING

A Modern Steam-Jet Furnace

Discussion of the elements involved in the design of an efficient forced-draft steam-jet furnace, with particular reference to the turbine furnace.

The steam-jet forced-draft furnace is of particular interest to the gas industry in that under proper conditions it provides a means of burning coke and coke breeze under steam boilers. A furnace of this description has a number of advantages; however, in some makes there are also disadvantages. Of these are mentioned the inequality of the intakes at different parts of the grate, excessive consumption of steam at the nozzles, wet flue gases and excessive back draft when the fire doors are open with steam nozzles full on, together with the fact that a large amount of fine coke breeze falls unburned between the bars.

Some of these difficulties have been solved by the use of the hollow longitudinal trough type of firebar, in which the air-steam blast is directed into the inside of the bar only with an entirely open ashpit, each bar having its own independent steam nozzle and the blast passing upward between small segments in the bars to the fire above. Even here, however, the inequality of the air blast is not entirely eliminated. The turbine furnace consists essentially of four or five longitudinal heavy cast-iron trough firebars placed side by side in the boiler-furnace tube according to the width. A cross-section shows a maximum width in the trough of 5 in., while the bottom of the trough is not longitudinally horizontal, but tapers upward from the front to the back of the boiler. This is correct in principle, since the volume of air passing along the trough diminishes as the length increases and more and more air is passed to the furnace above, and the angle at the bottom of the trough is designed to correspond exactly with the gradually reduced volume of air.

These trough firebars have lips at each end which hook over ridges on the deadplate in front and the bridge at the back, by means of which the bars are entirely supported; and the two bars nearest the furnace walls have special cast-iron angle sectional extension pieces to make good any gap and prevent all air leakage. The turbine is placed lower in the boiler-furnace tubes than the ordinary grate or most other types of steam-jet furnace, as it is maintained that this increase of combustion space gives more efficient results, particularly in the case of a bulky fuel like coke. The deadplate is accordingly sloped downward, and supported on existing bearer brackets.

A low firebrick bridge is built at the end of the grate in the ordinary way; but 18 to 24 in. behind a second and higher bridge is added, thus forming a combustion chamber which is claimed to aid the combustion of all fuels; and in the case of very finely divided material, containing a fairly high volatile content, it is advantageous to supply a small amount of secondary air underneath to this chamber so as to complete the combustion.

Placed transversely in these large trough firebars are a large number of small cast-iron firebars or "elements" of special design which slip transversely into the trough, interlocking one behind the other; 42 of these elements, for example, forming a 6-ft. composite firebar. Each element in the standard design has a narrow air slit ($^1/_8$ in. wide) between, so that the actual surface of the grate is composed of several hundred small transverse solid firebars, with an $^1/_8$-in. slit between, giving in the first place a very even and subdivided air supply at every part of the grate. The design of these small elements is on lines not easy to describe. They rest loosely on each edge of the trough firebar, and are provided in front with a slot, and behind with a flat web or feather which fits in the slot of the element in front; and through this locking member an inclined tapered air slot or passage is formed by the engagement of the back edge of the feather of one element with the back of the recess in the succeeding element. The rear face of the blade of each element is at an angle of 45 deg. to the top surface of the grate, and the forward face of the succeeding casting makes an angle of 60 deg. to the same plane, the $^1/_8$-in. air slit being really the end of an inclined tapered passage. This dips or projects into the trough—that is, into the current of air and steam—so that an equal amount of the blast under pressure is diverted up each of the tapering passages, and the same amount of air and steam passes up into the furnace through each of the several hundred slits, the velocity and pressure of the air remaining constant at every section of the trough length. This design of the turbine furnace is really based on the DeLaval steam turbine, for the firebars and the air trough are made to resemble as closely as possible the blades and the steam jet of a steam turbine of this character.

With regard to the design of the steam-nozzle mechanism, the ends of the trough firebars are in the form of elongated cast-iron throats or injector pipes bolted to the ends of the bars, projecting under the firebars, and the being protected by a hinged sheet-iron ash-cover ledge under the fire doors. These throats or injector pipes are 21 in. in overall length, $3^1/_2$ in. in diameter at the inlet, and contracting for the first 3 in. to $2^1/_2$ in., then parallel for the next 6 in., and finally expanding for the rest of the length to 4 in., to fit the radius of the bottom of the trough firebars. The steam jets consist of $^3/_{32}$-in. brass nozzles attached to a main steam-supply pipe for all the bars constituting the furnaces of the boiler. These jets are of special design, only arrived at after long experiment, and are stated to have the large coefficient of expansion of 0.67 (being equivalent in this respect to the ordinary $^1/_{16}$-in. nozzle), the jet spreading out immediately at a very wide angle and filling the whole of the injector throat a few inches from the nozzle.

The steam supply is also superheated, being taken through a $^1/_2$-in. pipe from the boiler front and then passed a short way into side flues of the boiler on the way to the nozzle pipe. The steam-pipe circuit to the nozzle includes a regulating valve, reducing valve, and pressure gage, so that the intensity of the air blast can be altered instantly; the draft pressure obtained being approximately 0.10 in. of water for each 10 lb. steam pressure on the nozzle.

The original article refers to tests made in large steel works in which three Lancashire boilers were equipped and the following data are said to have been obtained.

As regards the amount of steam consumed by the nozzles, the exact figure of the tests was approximately 3 per cent of the steam production of the plant. Thus in a given 24-hr. test the water evaporated in the boilers was 487,260 lb., and the steam used at the nozzles 15,370 lb.—that is, 3.1 per cent. This is a highly satisfactory figure, because of the efficient design, and very different from the 5 to 10 per cent of the steam production used by some steam-jet appliances, and means at the same time absolutely dry flue gases. The results of the determination of the air pressures at all points of the grate are given in the form of curves showing the details of the pressure in the furnace at every stage of the length, using four different steam pressures at the nozzles (100, 75, 50 and 25 lb.)—that is, four different intensities of blast. The total overall length of bars was 6 ft. 9 in.; but 1 ft. 6 in. of this is taken up with the solid inclined bedplate, so that the actual bar length

is 5 ft. 3 in., while the effective "air-space" length is about 4 ft. 10 in. Taking the 50-lb. nozzle-steam-pressure curve as the figure most generally used of the four, there is, of course, in the actual throat of the bars a high suction caused by the steam nozzle; and this commences at about $^1/_4$ in. of water level with the rim of the throat, and then very rapidly increases to $1^1/_2$ in. of water at some point about 3 in. in the throat. The pressure curve rises sharply until, when about 9 in. in the throat, it is atmospheric—that is, 0 in. of water. The curve goes on rising until, at $13^1/_2$ in. from the front of the throat and still about 8 in. from the deadplate end, it is at the maximum pressure of 0.80 in. of water. From here to the commencement of the actual air spaces to the furnace where combustion takes place, the curve (right to the bridge) is almost a dead-straight line—good testimony to efficiency.

The new modification of the "turbine" furnace to overcome this difficulty is the simple and ingenious plan of using special elements, containing between them, in place of a $^1/_8$-in. air slit, eight or nine tiny slots or holes. The surface of a 6-ft. grate contains, therefore, over 2000 of these slots, so that the fine material does not fall through; while at the same time the air supply is so subdivided that it does not blow the material off the bars, but enables a bright homogeneous fire to be maintained. Thus, for example, with anthracite dust the ordinary standard "turbine" furnace will evaporate about 3000 lb. of water per hr. in a standard 30-ft. by 8-ft. Lancashire boiler. With the new slotted "elements" the figure is 5000 lb.—practically equal to the best coal; and it may be stated that anthracite dust is more difficult even than coke-breeze dust. Finally, the "turbine" furnaces is applicable to every type of boiler, including the smallest verticals, and has now been proved, on the large Vancouver ferry steamers, to be very suitable for marine conditions also. (*Gas Journal*, vol. 163, no. 3149, Sept. 19, 1923, pp. 870–872, 5 figs., *gd*)

GAS ENGINEERING (See Fuels and Firing, Physics)

HYDRAULIC ENGINEERING (See also Physics)

Tests on Hydraulic-Turbine Governors

THIS article is composed from data supplied by A. F. Bang, Superintendent of Operation, Pennsylvania Water and Power Company, under whose direction the tests were made. The investigation was to determine the alleged failure of the hydraulic units of the Pennsylvania Water and Power Company at Holtwood, Pa., to carry their share of the load swings.

One of the possibilities investigated was that of insensitiveness. By insensitiveness is meant in general a measure of the governor's inability to maintain constant speed on the unit. It may be considered under two headings: (1) "Detention of friction," which prevents the governor from responding readily to load charges; and (2) "delay in restoration," which means the interval between the load change and the return to normal speed. The first of these is due to friction in the governor mechanism, while the second is in addition dependent on flywheel effect, fluctuation in wheel-pit pressure, traversing time of governor and relay, and the various governor adjustments. Both of these affect the distribution of load swings between the steam and hydraulic units. If the latter are slow in starting and restoring, the greater part of the large load swings will be shifted over on the steam units, and on small load swings the hydraulic governors may not get into action at all. Unequal division of load swings between steam and hydraulic units must to a certain degree be expected when they are operated in parallel, unless the frequency requirements of the system are such as to permit a slowing down in the action of the steam governors to make them correspond to the hydraulic governors.

The action of the latter, especially with reaction-type turbines for high heads, cannot be speeded up beyond a certain point. On sudden load reductions by the unit it is unpractical to close the gates too quickly, because even if the mechanism will stand the strain, the sudden retardation of the large water column in the penstock will build up pressure in the wheel pit which may have an effort greater in proportion than the decrease in volume of water and actually result in momentarily speeding up instead of slowing down the unit, thus defeating improvement in regulation. Again, on sudden opening of the gates the water column requires time to accelerate, depending on the slope of the penstock, and regulation is thereby limited in this direction.

The governors are water-operated and the flyballs control the pilot valve which operates through one or more relay valves to move the gates in the proper direction. The gates are in turn connected back to the pilot valve through links acting in connection with a spring and dashpot. Any movement of the gates tends to return the pilot valve to neutral, but the time required for them to do so is dependent on the dashpot adjustment. This adjustment, by controlling the time the pilot valve is permitted to remain open, fixes the new position of the gates which should exactly correspond to the new load.

A very interesting feature of the tests was the use of the oscillograph, selected as the best available means of securing a graphic record of governor performance.

The interesting analyses of the oscillograms cannot be reported here because of lack of space. It was found on the whole that there is an irregularity in the time elapsed between the load change and the first movement of the gate, due probably to the tendency of the governor to hunt, both while the unit is loaded and while idling.

Two other features somewhat briefly discussed in the original article are the comparison of kinetic energy stored in the hydraulic and steam units, and the influence of reactance. (*Power*, vol. 58, no. 15, Oct. 9, 1923, pp. 560–564, 9 figs., *eA*)

INTERNAL-COMBUSTION ENGINEERING

A Horizontal Compressorless Diesel Engine

DESCRIPTION of small compressorless Diesel engines of German make (Deutz). As shown in Figs. 2 to 4, the piston head fits into

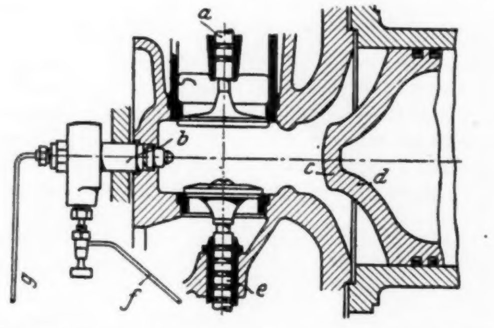


Fig. 2 Position of piston prior to throttling the ring space

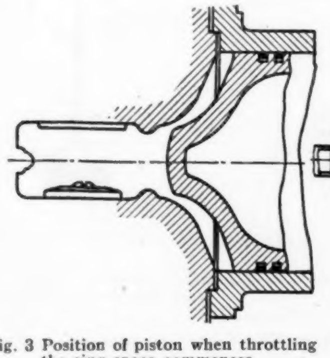


Fig. 3 Position of piston when throttling the ring space commences

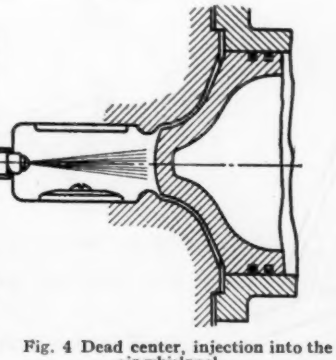


Fig. 4 Dead center, injection into the air whirlpool

FIGS. 2 TO 4 COMBUSTION CHAMBER OF A 30-HP. DIESEL ENGINE

the neck of the combustion chamber (Fig. 4) in such a way as to leave a small clearance. When the inner dead center is nearly reached the air is forced out of the cylinder into the combustion chamber in the form of a thin annular jet which sets the contents of the combustion chamber into a whirl. Indicator diagrams, it is claimed, show that this whirl reaches its greatest intensity shortly before the dead center. At that instant the injection of the fuel begins in the direction of the cylinder axis (Figs. 3 and 4). The ignition of the first oil particles is believed to intensify the whirling in the combustion chamber.

It is claimed that for a wide range of output the fuel consumption was less than 200 grams (0.44 lb.) of fuel per hp-hr. The original

article gives curves showing the heat balance of a 60-hp. engine which indicate very favorable conditions of operation.

An important advantage claimed for the Deutz engine described here is its adaptability to a wide range of fuels due to the fact that fuel prior to its ignition does not come into contact with cold injection air, but is subjected to preheating in the nozzle and is then directly injected into the hot whirling air. Furthermore, the engine can be arranged so that it will operate alternately with liquid and gaseous fuel. Thus it is able to operate for a time with crude oil and then change over to work on producer gas from wood or refuse materials. The inlet roller lever control of a 100-hp. engine for changing over from gas to heavy oil and vice versa is illustrated and briefly described in the original article.

The cooling water flows in two separate streams through the cooling jacket and the cylinder head, so that the cooling water heat is utilized as much as possible and cooling can be regulated in accordance with the load on the machine.

When starting with compressed air, it is of essential importance that no fuel shall enter the combustion chamber during the starting in order to avoid misfires with which are combined excessive combustion pressures. The fuel supply of the Deutz engine is automatically locked as soon as the operating lever is placed in the starting position, whereby the starting air inlet to the cylinder is simultaneously opened. (Horizontal Diesel Motor without Compressor, *Engineering Progress*, vol. 4, no. 9, Sept., 1923, pp. 181–184, 15 figs., *d*)

MACHINE DESIGN AND PARTS (See Pumps)

MOTOR-CAR ENGINEERING

Revolutionary Transmissions

Description of three systems of transmission designed to eliminate the clutch and gear box. One of the features of all of these systems is that they provide a wider variation in rates of speed than the conventional types.

The de Lavaud System was shown at the recent Paris salon on the Voisin stand. It is an infinitely variable system which automatically adjusts its gear ratio to the circumstances as required, the ratio being gradually lowered on a gradient and raised on regaining the level without any attention from the driver.

In principle the de Lavaud gear may be compared broadly with a hydraulic gear which has been converted to a mechanical system. In the hydraulic transmission, such as is used in training gun turrets, a pump transmits a number of impulses by oil pressure through valves to prevent loss on the return stroke to a hydraulic engine, the gear ratio being altered by varying the pump stroke. Substitute connecting rods for the oil column and its plungers, and put free wheels in the place of the valves—their duties are the same, to allow freedom in one direction only—and the similarity becomes complete.

The actual construction is, of course, very different and a great deal simpler. Mounted on the shaft, which in ordinary rear axles carries the bevel pinion, is a "wabbleur" or swash plate, anchored, by a universal joint, to a cage carried in the casing. This swash plate does not merely rock to and fro, but, although not itself rotating, wobbles like a coin at the end of its spin, so that the connecting rods attached to it are in turn moved the same amount. The connecting rods operate the one-way clutches or free wheels which drive the axle shaft. These clutches are of a special type designed to grip instantly; they are hardened and ground all over, and are rather like cageless roller bearings in which alternate rollers have been replaced by self-jamming cams.

With a top gear ratio of 4 to 1 and six connecting rods there are thus twenty-four overlapping strokes imparted to the rear-axle shaft in each revolution, and on a lower gear, say, of 16 to 1, there are 96 strokes. In another type, for lower ratios, there are only four connecting rods; in any case the movement is to all intents continuous, the extent of variation being comparable only with that due to a universal joint.

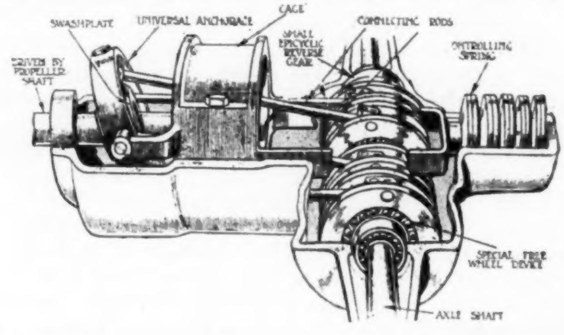


Fig. 5 Diagrammatic View of de Lavaud Variable Gear

The automatic adjustment of the ratio is obtained by altering the angle of the "wabbleur" so that the stroke to the connecting rods is varied. Thus when the resistance of the road wheels is low, the stroke is long and the gear high. When a hill is encountered, or any other resistance is met, the stroke is shortened, and a lower gear is provided.

The Healey Variable-Speed Gear Box is so designed that the belt and pulleys are replaced by an inverted toothed chain running on expanding sprockets. The segments of the sprockets are mounted between two sets of plates so that there are two plates on each side of the segments. The outer plate on each side has cut in it radial slots into which projections on the sides of the sprocket segments fit. The inner plates, however, have cut in them curved slots which also engage with the ends of the segments, so that when the plate with the curved slots is rotated in relation to the plate with the radial slots, the segments of sprockets are expanded or contracted.

The six segments when expanded do not form a complete sprocket wheel; in fact the chain has certain curved portions where it laps over the expanded sprockets and flat portions where it is free, and this allows the chain to adhere to the segments so that the tooth form is preserved whatever the diameter of the sprocket may be. The sprockets are also so mounted as to be capable of a certain

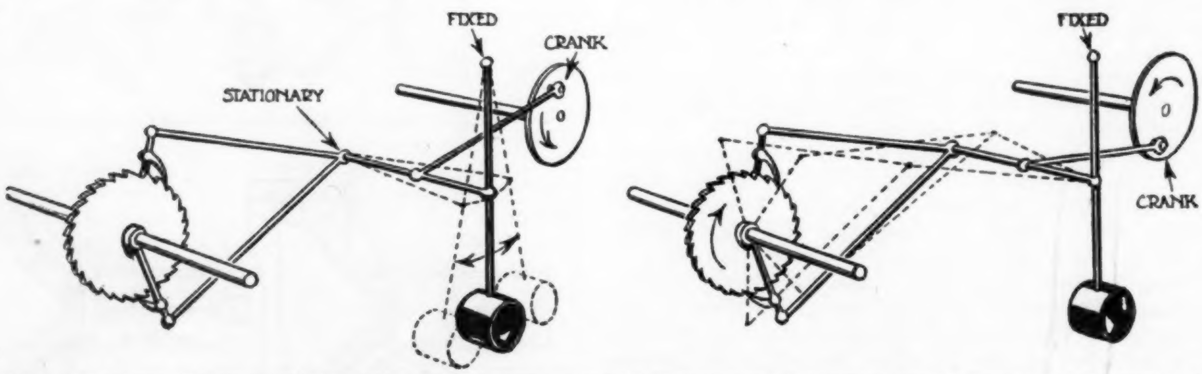


Fig. 6 Diagrams Showing the Principle of Operation of the Constantinesco Pendulum and Ratchet Transmission Gear for Motor Cars

(Left: Pendulum swings when the crank turns slowly, the ratchet wheel remaining stationary. Right: On speeding up the crank tends to come to rest, movement oeing thus imparted to the ratchet levers.)

lateral movement. At the present time the Healey gear is employed for the transmission of power in factories and is being developed for use on automobiles.

The Constantinesco Variable Gear is largely in the development stage. It is of the pendulum and ratchet type. The gear forms the only connection between engine and rear axle, displacing both clutch, change-gear box and axle-gear drive. Referring to Fig. 6, the shaft on the extreme right is the driving member, suitably cranked so that it transmits reciprocating motion instead of rotary motion to the transmission. A connecting rod unites this crank to a beam resembling somewhat the arm of a pair of weighing scales, except that it is lying horizontally. One end is attached to a pendulum, while the other has mounted upon it two links that form part of a ratchet gear, which, in Fig. 6, may be considered as the final drive to the rear axle. If the driving shaft be imagined to be slowly rotated, it will transmit a pull-and-push motion to the balance beam, and the connecting rod will prefer the easier task of oscillating the pendulum to that of driving the car through the ratchet.

A pendulum is usually associated in the mind with timekeeping, but in this instance its periodic swinging movement is not utilized. It is merely a mass weight, and its resistance to change of motion is the only function used.

Referring to Fig. 6, if the initial speed of the driving shaft be increased the effort required to oscillate the mass weight of the pendulum will also increase to a considerable amount. Its resistance to such movement will have the effect of impeding its movement and that of the connecting arm, consequently the other end of the balance beam will now commence reciprocating, together with the two links attached thereto. As these links are attached to the driven shaft by two short arms, the effect of this reciprocating motion will be to cause them to open and shut like scissor blades. As they open, the lower pawl will cause the ratchet wheel to rotate, and, while they are closing, the upper pawl will continue the motion. If the reciprocating movement be great, the ratchet wheel will revolve a considerable distance at each revolution of the driving shaft, corresponding to a high gear. On the other hand, minute but high-frequency oscillations will cause the pawls to have a minimum of movement, the ratchet wheel turning slowly under the influence of an exceedingly rapid series of impulses. This is the secret of the slow speeds obtainable, combined with a high turning effect. In a car fitted with such a gear the engine would always be in gear and control would be entirely by throttle. (*The Autocar*, vol. 51, no. 1460, Oct. 12, 1923, pp. 647–649, illustrated, *d*. The de Lavaud and Constantinesco gears are also described in considerable detail in *Automotive Industries*, vol. 49, no. 17, Oct. 25, 1923, pp. 830–833, 6 figs.)

PHYSICS

The Flow of Fluids

THERE are six variables of prime importance in the handling of both liquid and gaseous fluids on an industrial scale. These are the pressure drop or loss of head, the diameter of the pipe line, the length of the pipe line, the velocity of flow or a related quantity, the volume transmitted, and the density of the fluid and its viscosity. Problems arising in connection with the design or operation of equipment for handling fluids usually involve a calculation of one of these quantities, the five others being known or assumed. The usual problem involves the calculation of the pressure drop that will result when a given fluid is conveyed at a stated velocity through a given pipe line, or of the diameter of pipe necessary, or of the transmission capacity. Occasionally the length of line is the unknown and there are a few cases where one may wish to know the density or viscosity of a fluid that will cause a certain pressure drop in a given pipe line when a known volume is flowing. The calculation of pressure drop or length is comparatively simple, but the calculation of the other quantities is not so simple, involving a trial-and-error method that is in many cases time-consuming and is apt to be very confusing to the uninitiated. The purpose of this note is to point out a simpler method for calculating these quantities which is applicable in practically all of the cases that arise in practice.

Among other things, the author gives a process for the calculation of the pressure drop p, where l (pipe length), d (pipe diameter in inches), u (average velocity of flow in feet per second), s (specific gravity of fluid), and z (viscosity) are known.

The solution depends on whether the flow is viscous or turbulent, and several methods of solving the problem are indicated. The author offers also a simple and certain method for the solution of problems in cases where the type of flow is uncertain.

The author considers also the case of the calculation of the transmission capacity or velocity of flow and shows how to draw the p-V curves when the other magnitudes involved are constant.

Attention is called to the part of the article discussing what might be called critical magnitudes, such as critical diameter and critical volume, also critical viscosity and critical density as affecting the flow of fluids. (Barnett F. Dodge, Chemical Engineering Dept., Harvard University, in an article entitled Simplifying the Solution of Problems of Fluid Flow, in *Chemical and Metallurgical Engineering*, vol. 29, no. 19, Nov. 5, 1923, pp. 844–846, 3 figs., *tm*)

POWER-PLANT ENGINEERING (See also Testing and Measurements)

Utilizing the Waste Heat from the Cupola

DISCUSSION of the application of waste-heat-boiler recovery to cupolas. In the average cupola 8 lb. of metal are melted by each pound of fuel. The actual heat used in melting 8 lb. of iron and raising its temperature to about 100 deg. fahr. above its melting point is approximately 4000 B.t.u. and the heat value of the average

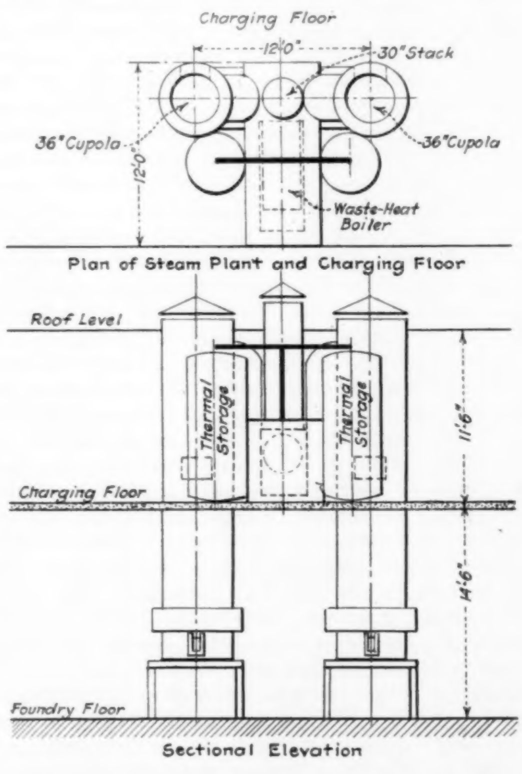


FIG. 7 WASTE-HEAT-BOILER PLANT AND THERMAL STORAGE TO UTILIZE THE WASTE HEAT OF TWO CUPOLAS

foundry coke is 12,000 B.t.u. per lb. One has therefore a balance of 8000 B.t.u. from each pound of coke burned for purposes other than melting. Assuming that a quantity of heat equivalent to that required for melting is used in maintaining the temperature of the cupola lining, etc., there is still available 4000 B.t.u. per lb. of coke for other purposes.

The author presents a table showing that in an 18-in. cupola there is available in waste heat per hour 375 B.t.u., in a 48-in. cupola 8,248,000 B.t.u., and in a 72-in. cupola 17,500,000 B.t.u. per hr.

The author states that he has accomplished several economies by the use of the waste heat. Fig. 7 is the plan and elevation of a waste-heat-boiler and thermal-storage plant, the steam from which is used to heat an office building. When neither of the

cupolas is in operation the steam is drawn from the thermal storage tanks, which will maintain the supply for practically 24 hr.

Fig. 8 is the elevation of a core oven utilizing the waste heat from a 36-in. cupola. An auxiliary firebox is provided but is to be used only when the cupola has not been in operation during the preceding day. (G. Ernest Booker in *Iron and Steel of Canada*, vol. 6, no. 10, Oct., 1923, pp. 211–212, 1 table and 2 figs., *dp*)

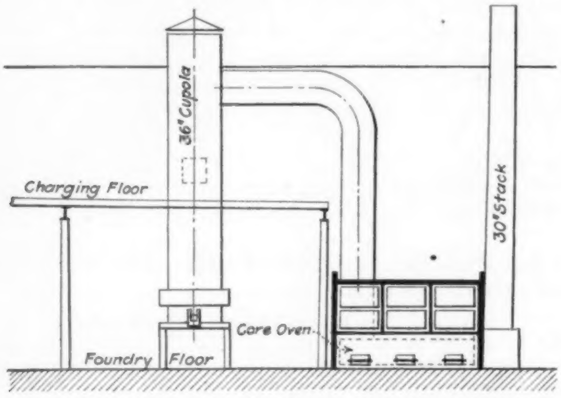


Fig. 8 Core Oven Heated by Waste Heat From Cupola

Steam-Boiler Practice in the Anthracite Region

It is only under the stress of economic conditions that the anthracite mining companies have a sufficiently large market to absorb the great quantities of buckwheat, rice, and barley coal—frequently called buckwheat Nos. 1, 2, and 3, respectively. By adopting the best methods of burning these small sizes in their own power plants the coal companies at the same time create their own market for small sizes and release large volumes of the salable sizes of coal for outside markets and consequently for domestic consumption.

Because of the necessity for a small ratio of heating surface to grate surface, only small boilers were at first used so as to make it easy to install grates as large as required without resorting to those of excessive depth. As the size of the boilers was increased the maximum depth of the grate was fixed at 7 ft. and the boilers so designed that the heating surface per foot of furnace width was kept small. This was accomplished in boilers of the bent-tube type by using a small number of short tubes per section, and in the straight-tube type by using sections not over nine tubes high.

Next, deeper grates were developed by moving the bridgewall toward the rear of the boiler the required distance which made possible the use of units of approximately 500 hp. rating in which the ratio of heating surface to grate surface does not exceed 35 to 1, and in which the furnace width does not exceed 15 ft. This is the limit in size of hand-fired units, unless the width is increased or units used which are fired from both ends. The use of larger units of moderate width has, however, been made possible by the installation of forced-blast chain-grate stokers, which marks the latest stage of accepted design in this field to date.

Exhaustive experiments undertaken in using anthracite fuel in pulverized form have been carried to such a stage as to warrant the statement that burning anthracite in this form will be the next step in the advance from present methods. The greatest difficulty seems to be in the crushing of the fuel rather than in its combustion. This has led to the consideration of a better preparation of the fuel before powdering by removing much of the abrasive ash before it goes to the pulverizers. This in turn has led to the suggestion that such preparation be given to coal that is to be burned without being pulverized. In view of the loss occasioned by the quantity of carbon in the ash and the high amount of ash when the coal is either hand or stoker fired, it would seem that the adoption of such a practice would produce real results in economy and capacity in both hand-fired and stoker-fired furnaces.

Data quoted in the article indicate that the loss due to carbon in the ash is the most serious one encountered in burning this kind of fuel, but much heat is lost in the flue gas; in fact, the loss is larger than when burning other kinds of coal. This is due in part to three things: first, the excess air necessary to effect combustion; second, the difficulty in obtaining the mixture of the excess air with the gas distilled from the coal; and, third, the slowness with which combustion takes place under the best conditions. Other causes of losses are also discussed in detail.

A pressure equivalent to nearly 2 in. of water is required to burn 25 lb. of No. 3 buckwheat per square foot of grate surface per hour, which is equivalent to approximately 150 per cent of rating for a boiler with a ratio of heating surface to grate surface of 30 to 1. If the boiler is of the straight-tube type with the bank nine tubes high the draft loss would be equivalent to not quite $^1/_2$ in. of water, and a stack 110 ft. high would be required to overcome this resistance. It was only after many years that this condition was fully realized, and it is only quite recently that correct plant design has been developed to deal with it.

A development in the design of the traveling chain grate has been the placing of an arch over the rear of the stoker surface so that the gases which have passed through the rear part of the grate pass over the surface of the fuel bed in a direction opposite to that of the travel of the grate and throw any particles of incandescent carbon which have been lifted from the grate by the blast toward the front of the grate. This construction has been remarkably successful, yet its control is still largely dependent upon the operator.

Another difficulty is presented in the removal from the fire bed and the disposal of the large quantity of ash resulting from the combustion of the small sizes of anthracite.

Several ingenious ways of handling the ashes by flushing have been devised. In some of these the ashes are flushed directly into abandoned workings in the mines for surface support, but in others, notably at the Nanticoke and Hampton plants of the Glen Alden Coal Co., where this opportunity does not exist, the ashes are flushed into wells from which they are removed by clamshell bucket and crane.

As already noted, the principal source of loss in burning small sizes of anthracite is in the large percentage of carbon in the ash. No changes in the design of the hand-fired boiler itself suggest themselves to remedy this, but great economies may be accomplished by cutting down the rating at which it is necessary to operate the boilers. (M. M. Price, Mem. A.S.M.E., in *Coal Age*, vol. 24, no. 21, Nov. 22, 1923, pp. 767–772, 4 figs., *td*)

PUMPS

A New Type of Rotary Pump or Compressor

Description of the Hill Rotors, Inc., motor-compressor unit having rotors of an apparently new type and said to be capable

Fig. 9 Rotors in the Hill Pump or Compressor Unit

of handling pressures from 20 to 400 lb. at any speed up to 2000 r.p.m.

Two rotors are employed, one inside the other, the outer one having nine lobes or teeth, and the inner one eight. The curves of these rotor lobes are such that they have a continuous pressure-

holding engagement between the high-pressure port and the low-pressure port.

The outer rotor drives the inner rotor, and air or liquid in one of the spaces never slips back between the lobes into the next larger space behind it. Each space does its own compression and discharges independently of its neighbor. These rotors rotate on fixed centers, the inner rotor being eccentric to the outer so that they open a series of spaces on one side to receive the pumped fluid and close them to discharge it on the other side.

Due to the pressure-holding engagement between the rotors and the positive mechanical action, pressure and volumetric efficiency are practically independent of the speed of rotation. The only factor to vary with the speed is the capacity.

On test a small paint-spraying air compressor had a volumetric efficiency of over 90 per cent at 50 lb. pressure. A small liquid pump had between 95 per cent and 100 per cent volumetric efficiency on pressures up to 100 lb. These pumps have attained pressures up to 370 lb. on air and 400 lb. on liquids. In both cases when attaining these pressures the power was shut off to save the piping.

Due to the fact that there is practically no clearance between the rotors, Hill rotors, it is claimed, will pull as perfect a vacuum as can be measured on a mercury column. (New Principle Discovered in Pump and Compressor Rotor Design, *Marine Engineering and Shipping Age*, vol. 28, no. 11, Nov., 1923, pp. 690, 2 figs., *d*)

RAILROAD ENGINEERING (See Testing and Measurements)

REFRIGERATION (See Thermodynamics)

SPECIAL PROCESSES

The Anglo Process of Galvanizing

DESCRIPTION of a process which belongs to the class of cold processes and which is claimed to give iron and steel surfaces a thoroughly efficient coating of zinc. It is being worked in England at Brentford and Sheffield by the Anglo Galvanising Co., Ltd.

This method consists in immersing the parts to be galvanized in tanks containing a dilute solution of zinc salts; by sending an electric current over it, it decomposes and the metallic zinc is deposited on the articles. The positive pole consists of sheets of zinc immersed in the same tank.

The coating of zinc in the new process is perfectly smooth, homogeneous, and compact, not porous, so that it can be compared with rolled compressed stock. This is very important, and is the principal factor that renders this new process perfectly adapted to the requirements of a good protection. The resistance to corrosion is higher than in the case of coating by the hot process, and this can be easily tested by immersing two pieces of iron galvanized by the two methods in two acid solutions of the same density. The results of a number of experiments made on different samples are given in Table 1.

TABLE 1 GALVANIZING TESTS

HCl, per cent	Quality of galvanized stock	Beginning of reaction after immersion, min.	Stopping reaction after immersion, hr.	min.	Reaction continuing after immersion, hr.	min.
30	Hot process	2	1	20	..	..
	Usual electrolytical process	1	0	7	..	..
	Anglo process	5	..	..	1	50
10	Hot process	4	17	0	..	..
	Usual electrolytical process	4	5	0	..	..
	Anglo process	14	24	0	..	..
5	Hot process	7	24	..	..	..
	Anglo process	10	..	..	24	50

The quantity of zinc used in these experiments was as follows: Anglo process, 300 grams per sq. m., giving a coating of 1 oz. per sq. ft.; hot process, 500 grams per sq. m., giving 1.64 oz. per sq. ft.

Two months' immersion in sea water proved the perfect preservation of plates galvanized by the Anglo process and bent in the shape of a prism, while other plates showed a beginning of oxidation in the points in which a bend had been made; and while the surface of the former remained smooth, the surfaces of the latter were exceedingly rough. Several months of exposure of plates galvanized by this system to the action of the sea air did not affect the metal in the east.

The malleability of the deposited zinc and its perfect adherence to the iron is such that the galvanized piece can be bent and twisted in any possible way without detaching it. The adherence of the zinc is more important than its thickness, which can be gradually augmented at will, and is always uniform on all the surface, whatever the shape of the piece may be and however numerous the lugs, flanges, mortices, or core holes.

The process renders possible the substitution of thin sheets of steel for thick sheets of iron, the former giving the same efficiency with much less weight. The shipbuilding industry would be the most benefited by a method of galvanization which solves the problem so long sought of coating with an even stratum of zinc of any thickness and of perfect adhesion to iron or steel parts of large dimensions, and it is quite possible we may see by the adoption of this new process a complete revolution in the iron and steel galvanizing industry. (*The Iron and Coal Trades Review*, vol. 107, no. 2904, Oct. 26, 1923, p. 623, *g*)

TESTING AND MEASUREMENTS

Precise Length Measurements

THIS is the first of a series of lectures in which it is proposed to discuss and illustrate some of the more interesting facts, methods, and problems of present-day metrology; to give an idea of the degree of accuracy now attainable in the control of various types of length standards with the possible lines of developments and the difficulties and limitations attached thereto.

The principal primary standards of length in the world, the British Imperial standard yard and the International prototype meter, are both material standards, and in the event of loss and damage they may be replaced by reference to other similar bars with which respectively they have from time to time been most carefully compared. One such comparison has been recently completed and it was found that the results of this (1922) comparison in no case differed from those of 1912 by more than two hundred-thousandths of an inch, which is equivalent to about one part in two millions of the whole length of one yard.

The author proceeds to discuss the influence of temperature in measurements and to describe various comparators. A further difficulty is introduced in this kind of work by the fact that the constancy of the prototype meter is not entirely above suspicion, as during some recent recomparisons of a number of national copies of the meter at the Bureau International, Sèvres, certain differences appeared which on the average seemed to indicate that all these bars had shortened relatively to the International prototype by about four parts in ten million. This result appeared so improbable that a new and very elaborate investigation was undertaken, with the result that it was eventually found that the intermediate bars in use at the Bureau had themselves lengthened by four parts in ten million, and that the remainder of the variations which had been observed were due to the use of slightly erroneous values for the coefficients of thermal expansion of the various bars when calculating their lengths at 0 deg. cent. from observations made at or about room temperature—an explanation, by the way, which affords a most illuminating commentary on the value of the virtue claimed for the metric system that its standards are correct at the easily reproducible "scientific" temperature of 0 deg. cent., instead of at the convenient every-day working temperature of 62 deg. fahr., adopted for the British standard. But apart from this, the fact that two bars of the series should change relatively to all the others, and both by the same amount so that the change went for many years undetected, is clearly most disquieting, and cannot but introduce a certain degree of doubt as to the absolute stability even of the majority.

From this the author attempts to discuss various attempts to establish a so-called "natural" standard, with particular reference to the work of Prof. A. A. Michelson, who worked out a plan for determining the length of the meter in terms of the wave length of some particular kind of light. Wave-length measurements are of extreme delicacy and require great accuracy and care, and the author discusses some of the features involved and apparatus used, in particular the diffraction grating.

The problem of further advance in measurements resolves itself into these questions: (a) Can we improve the definiteness of our material standards? (b) If we can achieve (a), have we then any assurance as to the sufficient secular stability of the material standards themselves, or as to the possibility of applying increasingly stringent control by means of wave lengths or other natural standards?

In this connection the author advocates the use of natural-crystal quartz end standards as a future control for measures of length. Mention is made of improvements recently effected at the National Physical Laboratory in the perfection of mechanical finish of ordinary metal end standards. Novel methods of measurements briefly described in the original article permit of attaining in the manufacture of standards of length, degrees of accuracy about ten times superior to any previously attainable. Thus, it is possible to approach an accuracy of the order of one part in one hundred million on a one-meter length, but it is also well to remember that such an accuracy is obtainable only with the greatest care in measurement, and how great this care must be is indicated by the fact that there is in the present state of knowledge no guarantee that wave lengths of light from nominally identical sources and under nominally identical conditions can be reproduced within the very high degree of accuracy here in question.

A new control on standards of length has been developed as a result of the work on the electrical triode valves familiar to users of radio telephones. While the method cannot be described owing to lack of space, it promises to provide a process by which the permanency of the physical properties of a bar may be compared with those of the day, i.e., within one part in ten million per century, J. E. Sears, Jr.[1] in (*Journal of the Royal Society of Arts*, vol. 71, no. 3698, Oct. 5, 1923 , pp. 775–791, 11 figs., *d*)

THERMODYNAMICS

The Specific Heat of Superheated Ammonia Vapor

A SERIES of measurements of the specific heat of superheated ammonia vapor were made recently at the U. S. Bureau of Standards to supply data for tables of thermodynamic properties of ammonia suitable for use in refrigerating engineering.

The method employed in these measurements was the continuous-flow electric method, which consists of observing the rise in temperature produced by a measured electric power added as heat to a steady stream of vapor flowing at a measured rate. A special flow calorimeter was designed for making these measurements on ammonia, but may be used for similar measurements on other vapors and gases at temperatures below 150 deg. cent. and pressures below 100 atmos.

An expression for the specific heat at constant pressure for a definite temperature and pressure is developed which contains the three principal quantities observed, namely, temperature rise, power input, and rate of flow, and in addition correction terms for thermal leakage, pressure drop, and the variation of the specific heat with temperature.

The results of 108 complete experiments serve to establish the value of the specific heat at 35 points in the temperature range −15 deg. to + 150 deg. cent. (5 deg. to 302 deg. fahr.) and the pressure range of 0.5 to 20 atmos. Several determinations of the Joule-Thomson coefficient were made in order to evaluate the correction for pressure drop in the specific-heat experiments.

An empirical equation of the form, $C_p = f(p, \theta)$ was chosen to represent the experimental results within the range covered by the experiments.

Values of C_p computed from the empirical equation agree with the experimental values within 0.3 per cent in all cases. The average agreement is 0.07 per cent.

Previous measurements of the specific heat of ammonia vapor are briefly reviewed and tabulated.

A table containing values of C_p at convenient intervals of pressure and temperature accompanies the original paper. (N. S. Osborne, H. F. Stimson, T. S. Sligh, Jr., and C. S. Cragoe, in *Refrigerating Engineering*, vol. 10, no. 5, Nov., 1923, pp. 145–167, 18 figs., *teA*)

[1] Supt. of Metrology, National Physical Laboratory, and Deputy Warden of the Standards.

WELDING

Welding Cast Iron with a Special Nickel-Copper Alloy Welding Wire

THE author claims that a method has been developed of welding cast iron involving the absorption of the carbon content in cast iron and the formation at the juncture of the weld of a new alloy, the whole being accomplished without preheating, annealing, or the use of studs.

This welding is done with a special nickel-copper alloy of the following composition: Nickel, 66 to 68 per cent; manganese, 1 to 2 per cent; sulphur, maximum 0.09 per cent; iron, 1 to 3 per cent; and copper, 27 to 30 per cent. [It may be mentioned that this special nickel-copper alloy, as far as composition is concerned, does not materially differ from the high-manganese type of monel metal used for cold drawing and rolling of monel-metal products. EDITOR.]

This alloy flows through the arc differently from other welding metal and requires a certain amount of skill in operation. The coefficient of expansion of the wire closely approaches that of gray iron, and it is said that when it has been deposited it does not pull away from the gray iron as does a steel electrode.

The original article contains in addition certain practical instructions for carrying out the process and states that it has been applied successfully in a number of cases. (Alex. Churchward, of the Wilson Welder and Metals Company, in *Journal of the American Welding Society*, vol. 2, no. 9, September, 1923, pp. 17–19, 3 figs., *dp*)

VARIA

12-Hr. Day in United States Mint

ACCORDING to the Philadelphia *Public Ledger*, in the United States Mint in that city 300 men, expert alloyers and annealers, are forced to work 12 hours a day.

As regards wages, the expert men receive $6.18 a day and the helpers $4.50. Laborers receive approximately $3.00 a day for 8 hours work. All employees get straight time and not time and a half for the 4 hours of extra work.

According to a statement recently made by the Superintendent of the Mint, Frederick Chapin, the use of two shifts is due to limited appropriations. "Three shifts mean a loss of time when there is a demand for pennies, dimes, and quarters. It means increased clerical work as well." According to Civil Service regulations, it should be remembered, Government employees are not permitted to strike. (*Daily Metal Trade*, vol. 13, no. 191, Sept. 28, 1923, p. 1, *g*)

Success of Vocational School in Producing Gears

STUDENTS in the vocational school at Madison, Wis., are engaged in the production of 1000 gears for the Gisholt Machine Co., Madison, under an agreement with Joseph O. Johnson, director of the machine shop. The Gisholt company agreed to furnish materials and purchase gears if 75 per cent passed inspection at limits of 0.0002 in. It is found that 90 per cent of the production has met approval, rejections so far being two in 100 gears. The gears are worked on a Gisholt turret lathe of standard shop size, the only machine of its kind installed in a vocational school in the United States. Because of the efficiency reached in the production of gears, the Gisholt company has decided to compensate the school for the work it does, although the original agreement merely called for the furnishing of materials. The school is now installing a Gisholt time-recording system to accommodate this and other operations in the machine-shop department. (*The Iron Age*, vol. 112, no. 24, Dec. 13, 1923, p. 1589, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

The Salt Velocity Method

(Continued from page 16)

That a traverse with short final electrodes gives equally accurate results.

That the same electrodes held at a fixed point, determined by the traverse, also show accurate results.

That computations based on the center of area as determined by a watt-hour meter and a series of jump-spark dots simplify the work and give accurate results.

That tests can be repeated indefinitely and still check.

That the apparatus and methods of computation used in the commercial tests were proved to be theoretically and practically correct, and the results obtained were accurate and reliable.

Advantages Claimed for Salt Velocity Method

Among the advantages claimed for the salt velocity method of water measurement are:

1 *Simplicity.* Tests can be made with very simple apparatus either built in the field or purchased from stock. This is especially true of long pipes, the short penstocks demanding more elaborate apparatus and careful work.

2 *Accuracy.* It is as accurate as any other method and more accurate than most of them.

3 *Applicability.* The method is applicable to any form or size of flume, pipe, or penstock, and can be used on penstocks where most of the other methods are not at all applicable.

4 *Economy.* A greater number of accurate tests can be made with less labor and expense than by any other method. Multiple tests and checks can be made at a nominal added expense.

5 *Interruption of Operation.* The tests can be made with little or no interference with operation. In 1922, five tests were completed without emptying the penstocks or shutting down the wheels.

6 *Check Measurements.* The method can check itself by comparing the results by traverse with the results by composite curves.

7 *Flexibility.* By the throwing of a switch or two the method is instantly applicable to new conditions such as shifting salt introduction or final electrodes.

8 *Time Required.* Tests can be made quicker by the salt velocity method than by any other known method. In one day last year nearly 300 individual shots or tests were made on a 20,000 hp. unit.

9 *Records.* This method makes a permanent record of all the test events on the curves, independent of any personal equation, and the curves can be filed for future reference.

10 *Relation to Efficiency Results.* The practice with the salt velocity method of taking multiple shots extending over the whole period of a run, insures the integration of the discharge against the integration of the electrical load when the latter is measured by an integrating watt-hour meter.

11 *Results Quickly Computed.* Approximate values for discharge can be known before the end of a run, and frequently all the results of a day's testing have been accurately computed during the evening of the same day.

And finally, the authors believe that the salt velocity method is correct in theory and in practice, and that in a few years its simplicity, accuracy, and other advantages will make it an accepted standard method of water measurement.

Discussion

THE first of the written discussions to be read was that of H. K. Barrows,[1] who wrote that it would be of interest to study the use of the salt velocity method for determining discharge in open flumes and conduits of regular cross-section, as this appeared also to be a field of usefulness for it.

John S. Riddile,[2] in a written discussion, presented data of tests made at the Shawinigan Water and Power Company's plant with the salt velocity method, the average of which showed no difference between measurement in the 500-ft.-long circular penstock and in the combined discharge of the short, complex system of gathering tubes.

Clemens Herschel[3] wrote that methods of water measurement were after all only procedures to be used by engineers to arrive at certain desired results, and one should therefore consider in all cases whether it would not be better to meter continuously than merely to measure at disjointed times. From the number of power plants that were installing permanent venturi meters in their penstocks, Mr. Herschel inferred that many engineers believed metering to be the better choice.

[1] Consulting Hydraulic Engineer, Boston, Mass.
[2] Laurentide Power Company, Ltd., Grand Mere, Quebec, Canada
[3] Civil and Hydraulic Engineer, New York, N. Y.

E. B. Strowger,[1] cited data of two tests which were of special interest as they gave an indication of the accuracy with which measurements of water might be made by the Gibson method. One of these was with a 55,000-hp. turbine under a head of 312 ft. with a penstock 500 ft. long, and the other with a 10,000-hp. hydroelectric unit under a head of 212 ft. with a penstock 250 ft. long.

Paul F. Kruse,[2] wrote calling attention to the desirability of taking into consideration the practical relation of the pressure-time diagrams resulting from different heads and different types of turbine gates or penstock valves employed. He had found such consideration to be very useful in choosing the time and rate of closure and in the adjustment of the Gibson apparatus in order to obtain the most easily and accurately interpreted diagrams.

R. W. Angus,[3] who opened the oral discussion, said that the two methods differed in that Mr. Gibson's required momentary readings throughout, which meant that in getting the efficiency of the turbine the electrical measurements had to be made with very great accuracy. The salt velocity method, however, was one in which the average of the electrical results might be obtained, because the measurements could be continued over a considerable length of time, and it therefore seemed possible that even though the electrical measurements might not be made with absolute accuracy, the average over a length of time, as taken by a wattmeter, might give closer results in regard to efficiency.

H. Birchard Taylor,[4] commenting on the despatch with which tests might be made by the two methods described, recalled a test made seventeen years ago at Shawinigan in which two weeks were required for preparation and two weeks more to make the readings.

Thomas H. Hogg[5] said that the Hydraulic Power Commission of Ontario had been using the Gibson method for all of their work during the past three years in testing plants with heads varying from 50 to 550 ft. and penstocks 50 to 1500 ft. in length, totaling a turbine capacity of nearly a million horsepower, and that he had yet to find a case where the method was not all that could be asked for. In efficiency tests of turbines, however, he believed that the author should emphasize the fact that the measurement of power must be made with the generator at constant speed.

Wm. M. White,[6] who presided over the session, said the company with which he was connected had accepted Mr. Gibson's method unhesitatingly and that hardly a month passed but that it was written in some contract very definitely that the efficiency of the turbine to which it related should be determined by that method. In other contracts the Allen method or the salt solution method were specified. It was a question as to which method the engineer preferred.

Mr. Gibson, in his closure, said that he was not prepared to say what the minimum length of the penstock was where his method could be used. He had made successful measurements down to 70 ft. in length, but in no case had applied it to a pipe less than 50 ft. long. The lower limit could be determined only by experiment. The only reason why the length of pipe came into consideration was that as the pipe got shorter the impulse became smaller and therefore it would require more delicate means of measuring the impulse accurately. Otherwise there was no limitation except that which was common to all methods, namely, that of the determination of volume being perhaps more difficult with a short, irregular conduit than with a longer one, even if it was irregular.

R. D. Johnson[7] and L. F. Moody[8] also contributed briefly to the oral discussion.

[1] Niagara Falls Power Company, Niagara Falls, N. Y.
[2] Sanderson & Porter, New York, N. Y.
[3] Professor, Mech. Eng., Univ. of Toronto, Toronto, Ont. Mem. A.S.M.E.
[4] Vice-Pres., Wm. Cramp & Sons Ship & Engine Bldg. Co., Philadelphia, Pa. Vice-Pres., A.S.M.E.
[5] Toronto, Ont.
[6] Manager and Chief Engineer, Hydraulic Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis Mem. A.S.M.E.
[7] Hydraulic Engineer, New York, N Y. Mem. A.S.M.E.
[8] Cons. Engr., Wm. Cramp & Sons Ship & Engine Bldg. Co., Philadelphia, Pa. Mem. A.S.M.E.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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Developments in the Boiler Field

THERE have been fewer changes in boiler design from the days of Watt to, say, fifteen years ago than perhaps in any other part of the modern power plant. In the field of prime movers the uniflow engine, and especially the steam turbine, look utterly unlike anything in existence at the beginning of the nineteenth century. Entirely new members of the power-plant family have appeared since that time, such as economizers and air preheaters; and while the surface condenser resembles very much the apparatus built by James Watt some seven score years ago, the jet condenser is a decided innovation, working on a principle radically different from that of the original surface condenser.

That the modern boiler has a performance vastly superior to the Cornish or Lancashire types of 100 years ago there can be no doubt, and yet there is no question but what the steam engineer of days far gone by would feel at home in the boiler plant of today after an hour's acquaintance with the indicating and recording instruments. (This refers, of course, to the steam-generating end of the boiler only and not to the firing system.)

It seems to be a rule, however, the reason for which is fairly obvious that no sooner does a piece of mechanical equipment reach its final stage of perfection than it is displaced by something radically different. The Corliss engine shown at the Centennial Exhibition in 1876 was the biggest engine of its kind and in size it has never been surpassed, because only a few years after the exhibition the steam turbine appeared as a commercial product and the attention of engineers was diverted to this new prime mover.

Similarly in the last fifteen years there has been a tendency to break away from the Watt type of boiler and to build something that would work in an entirely new way. There are several such types now offered to the engineering trade. Blumquist, in Sweden, recently built a 1500-hp. boiler for the power plant of a sugar factory and adopted rotary tubes, throwing the water to the wall of the tube by centrifugal force and thus leaving a free steam passage through the center. Benson, in England, working along entirely different lines and utilizing in certain ingenious ways the balance between the critical temperature of the liquid and the critical pressure of steam formation at that critical temperature, has produced a steam generator operating with vapor having a pressure of the order of 3200 lb. per sq. in.

Another revolutionary development which is being promoted by the General Electric Company is that of the mercury-boiler plant, the invention of W. L. R. Emmet, Mem. A.S.M.E. The principle of the Emmet plant is very simple and by now well known. The difficulties involved, many of which had not been initially suspected, were tremendous, and it took more than ten years, coupled with the expenditure of very large amounts of money and effort, to overcome them.

There are still probably many stumbling blocks ahead of the new power plant on its way to commercial success. Statements have been made, for example, that should an attempt be made to introduce the mercury-vapor prime mover into general use there would not be enough mercury to go around. Dire predictions have also been made as to the effect of the "wet" mercury vapor, i.e., vapor containing globules of liquid mercury, on the turbine blades, and so on. To those, however, who remember the truly stupendous difficulties that lay in the path of the designers of steam turbines and that were successfully overcome when it became evident that the steam turbine had a great commercial future before it, it would seem that there is no valid reason for any decided pessimism on that account. Some difficulties have been overcome and there are more to be overcome, and the chances are that they will be. There is an undoubted shortage of mercury today, but it has been the experience of the past that whenever a mineral or material became really necessary to industrial progress, in some manner or other supplies were discovered. This, it will be remembered, was the case with iron ore, with tungsten, and quite recently with helium, and there are good reasons to believe that the prosecution of a vigorous search for cinnabar will disclose new supplies of this now desirable material.

From the point of view of the mechanical engineer the essential fact is that a new type of prime mover has passed the first and most critical stage of development and has become a mechanical if not yet a commercial reality to be reckoned with. Mr. Emmet and his associates in the General Electric Company are to be congratulated on bringing through its "teething" troubles what appears to be a husky and promising youngster.

The Political Obligations of the Engineer

PRESIDENT HARRINGTON'S address at the last Annual Meeting of the Society should furnish a powerful impetus to thought concerning the obligations and opportunities of the members of the engineering profession.

While President Harrington emphasized the growth of the engineering profession and its right to prominence, he found that many fundamental things are missing. He placed a sure finger on one great lack of the profession, and that is, that the educational system by which engineers are trained does not meet the requirements. The engineer's knowledge and aid are required in solving labor problems, in promoting engineering research, in advancing economics, and in producing beneficial results in transportation. The engineer, however, is politically weak, and, as President Harrington pointed out, he likes to sit in the background until deference is shown to his superior technical knowledge.

While President Harrington pointed out these shortcomings, he also emphasized the fact that the engineer has the power to attain through his own effort, and that first of all he must do his full political duty. He must enter political contests as members of other professions do, and as a citizen must give fully of his time and special knowledge to the public interest.

In the engineer's struggle to save the world he ofttimes loses sight of the importance of participating actively in the political life of his own community. Nowhere is the influence of the engineer and the sound business man more needed than in municipal problems, and it is in that field of politics that the engineer is well qualified to serve. The profession as a whole cannot take its place among the leading professions and guide in the large activities until its members have shown themselves willing and fit to give of their efforts in the solution of the problems of the municipality.

Calvin W. Rice,
Secretary, A.S.M.E.

The Increasing Demand for Power

THE growth of American industry depends in a large measure upon the provision of power in increasing quantities. In some metropolitan centers the power load has doubled in the last ten years and there is every reason to believe that the increase of labor-saving devices in our factories, the growth of popular demand for commodities that were once luxuries, and the proportional increase of the necessities of life with increase of population will accelerate the increase of power demand. In a discussion at the Hydroelectric Session of the recent A.S.M.E. Annual Meeting, Mr. William M. White pointed out that the wage rates of American workmen are twice those of British workmen because the horsepower per man in America is twice that in England. Productive capacity has a direct relation to the available horsepower. All this emphasizes again the importance of power to our civilization and makes necessary the complete understanding by the engineering profession and the public at large of the fundamental principles involved in the development of power from water, coal, oil, and gas. It was fitting and proper, therefore, that the American Society of Civil Engineers and the American Institute of Electrical Engineers coöperated with The American Society of Mechanical Engineers in a session to discuss one important phase of the power question, that of hydroelectric development.

The purpose of the coöperative session was to make clear the broad principles underlying hydroelectric development. The main paper, by John R. Freeman, and its discussion, which is given the leading place in this issue, will bear careful study by every engineer. While the fundamentals are simple, still the future procedure is not clear. Economies in the generation of steam from coal made possible by higher steam temperatures or the mercury boiler and the growing use of the oil engine are factors which must be reckoned with. The eventual system will of necessity utilize all possible agencies of power generation, each in its proper field and all correlated.

The interconnection of power systems is well under way. International and interstate relations are involved and must be adjusted. All this requires time and is dependent in some degree upon advances in the science of electrical transmission.

The purpose of this brief editorial review is not to state anything new or startling, but merely to emphasize again the importance of power in a civilization that offers "universal well-being," and to commend the subject to every engineer for study.

An Engineering Lending Library

A LENDING department has now been added to the service features of the United Engineering Societies Library. By this means any member of the four national engineering societies in North America may borrow from the excellent collection of modern American books on engineering, according to the rules set forth in another column of this issue of MECHANICAL ENGINEERING. This broadening of the Library service is a noteworthy step and a logical extension of the valuable service the Library has been rendering in furnishing photostats of articles in foreign books and in the technical press.

The accessibility of the wonderful engineering library in the Engineering Societies Building only to those who are able to visit it in person has long been a condition greatly to be regretted. Now that a lending service is extended to members of the four societies, the value of this excellent collection of books will come to be more and more generally realized. Our Library is now a tangible asset to every Society member.

To render engineering books available to the maximum number is a tremendous task. Engineering books are expensive. They treat narrow fields and are quickly out of date because of the tremendous strides of progress. True, all technical magazines publish authoritative book reviews which are helpful guides, but in the last analysis the engineer must see the book itself, weigh its conclusions, and decide whether it meets his needs. The lending service will permit this careful study. Inquiries sent to the library and the office of this Society clearly indicate that many engineers are not familiar with the great fundamental engineering books. This step to increase their availability will be greatly appreciated.

Wm. E. Wickenden to Direct Survey of Engineering Education

WILLIAM E. WICKENDEN, assistant vice-president of the American Telephone and Telegraph Company, has been appointed Director of Investigations of the Society for the Promotion of Engineering Education, in which office he will conduct an exhaustive study of engineering education. As reported in the last issue of MECHANICAL ENGINEERING, the Carnegie Corporation of New York voted a sum of $108,000, of which $24,000 is available during the present fiscal year, "for the purpose of making possible a study of engineering education under the direction of the Society for the Promotion of Engineering Education."

The underlying plan of the project is that the engineering colleges themselves, through committees from their faculties shall unite and coöperate in self-investigation instead of having some outside agency diagnose conditions and suggest remedies. This self-study, however, will be made with the active coöperation of industrial, professional, educational, and governmental agencies.

Mr. Wickenden, who has already begun his new work, has a wide knowledge of engineering education from the viewpoint of both the college and industry, and is well qualified and wisely chosen for the work. For a number of years he was a teacher in engineering schools. He left the position of associate professor of electrical engineering at the Massachusetts Institute of Technology to become supervisor of educational work, and later personnel manager, for the Western Electric Company. In 1921 he became assistant vice-president of the American Telephone and Telegraph Company. Thus his education, training, and interests have been fitting him for many years for the unusual position he has been called upon to fill.

The four national engineering societies have, upon request, appointed counselors to advise and coöperate with the Board of Investigation and Coördination of the S.P.E.E. William Barclay Parsons of the A.S.C.E.; Allen H. Rogers and William Kelly of the A.I.M.E.; Gano Dunn and F. B. Jewett of the A.I.E.E.; and John Lyle Harrington and Frank A. Scott of the A.S.M.E., are the counselors who have been chosen.

Relations with the industries will be entered into and maintained through a joint committee of the S.P.E.E. and the National Industrial Conference Board. The study will include a survey of European as well as of American conditions. The results of this study will undoubtedly have a marked influence on other educational groups.

Correction

FIG. 4 of the paper on The Water, Coal, and Man Power of the Western Slope of the Southern Appalachian Mountains, by Profs. J. A. Switzer and W. R. Woolrich, as printed on page 640 of

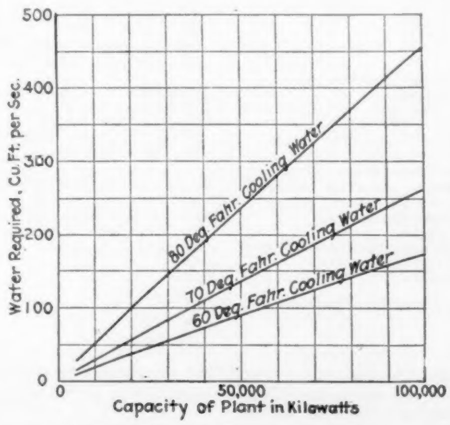


FIG. 4 CONDENSING-WATER REQUIREMENTS OF PLANTS OF VARIOUS SIZES WHEN OPERATING AT $28^1/_2$ IN. OF VACUUM REFERRED TO SEA LEVEL AND WITH COOLING WATER OF DIFFERENT TEMPERATURES

MECHANICAL ENGINEERING for November, 1923, embodied an error in the horizontal scale values. The figure as corrected in accordance with the original copy is reproduced herewith.

Engineering and Industrial Standardization

An Example of Standardization in German Industry[1]

AFTER a visit to Germany in connection with the International Standardization of ball bearings, Mr. Oscar R. Wikander made the following statement in a communication to the American Engineering Standards Committee:

There is no doubt in my mind that one of the main reasons Germans force their standardization work is because they are now firmly convinced that their former commercial policy in international trade must give way to a new one based on engineering and industrial standards.

It was only a few years ago that the "Normenausschuss der Deutschen Industrie," an organization corresponding to our American Engineering Standards Committee, was formed, but the amount of work which it has already accomplished is stupendous. The "Normenausschuss" has already issued several hundred sheets of approved standards, and about twice as many are already published as proposed standards.

This enormous output of the German organization has led many to believe that it was merely a factory producing "paper standards," and that its work was not to be taken very seriously. A personal investigation convinced me that this is not the case, and I found that the great output of standards was merely due to the enormous effort put forth and to the enthusiasm of the great majority of interested parties.

This enthusiasm is due to a more or less general recognition, created under the pressure of war conditions, of the great economic value of standardization, and to the very generally accepted opinion that a standardized industry would be one of the strongest weapons in Germany's struggle for economic rehabilitation and financial reconstruction.

TABLE 1 STANDARDS SHEETS—INDEX FOR GROUPS AND CLASSES

0	GENERAL RULES—BUSINESS ROUTINE
00	General correspondence
01	Standardization
02	Business routine and communications
03	Drawings
04	Drawings
05	Rules for delivery of raw materials
06	Rules for delivery of parts
07	Bureau and shop organization
08	Business papers, books, cards
09	Miscellaneous
1	MANUFACTURING RULES
10	Handling of the surface of metals
11	Finishing and fitting
12	Working metals hot
13	Coating
14	Working of insulated materials
15	Rules for winding
16	Connections
17	Rules for assembly
18	Test and acceptance rules
19	Miscellaneous
2	CALCULATIONS
20	
21	
22	
23	
24	
25	
26	Tools
27	
28	
29	
3	BASIC STANDARDS
30	Measurements and number series
31	Mechanical construction
32	Electrical construction
33	
34	
35	Tools
36	
37	
38	Marks, names, abbreviations
39	Miscellaneous
4	MATERIALS
40	Iron
41	Iron
42	Steel and alloyed steels
43	Brass, bronze, red brass, copper
44	Brass, bronze, red brass, copper
45	Aluminum, german silver
46	Various metals
47	Insulating materials, textiles, wood
48	Lacquer, oils, rosin, wax
49	Miscellaneous
5	HALF-FINISHED PRODUCTS
50	Iron
51	Iron
52	Steel and alloyed steels
53	Brass, bronze, red brass, copper
54	Brass, bronze, red brass, copper
55	Aluminum, german silver
56	Various metals
57	Insulating materials, textiles, wood
58	
59	Miscellaneous
6	CONSTRUCTION STANDARDS—MECHANICAL REQUIREMENTS
60	Screws
61	Screws and screw connections
62	Nuts and pulleys
63	Fastening and transmission elements
64	Fastening and transmission elements
65	Service elements
66	Scales, plates, studs, armatures
67	
68	Springs and spring parts
69	Miscellaneous
7	CONSTRUCTION STANDARDS—ELECTRICAL REQUIREMENTS
70	Connection and distribution elements
71	Connection and distribution elements
72	Contacts, switches, etc.
73	Insulated service elements
74	Resistances
75	Magnets and electromagnets
76	Hard rubber, porcelain, stealite parts
77	Coils and coil cores
78	Conductors, cables and fixtures
79	Miscellaneous
8	TOOLS AND GAGES
80	Hand tools
81	Boring, drilling, grinding tools
82	Milling tools
83	Cutting, molding, drawing tools
84	Turning, planing, and punching tools
85	Lathes and fixtures
86	Auxiliary tools
87	Measuring tools
88	Rubbing and polishing tools
89	Miscellaneous
9	MISCELLANEOUS
90	Detail standards
91	Standards of other plants
92	Standards of foreign societies
93	D I N General
94	
95	
96	
97	
98	
99	General

In view of this great German effort, it is most interesting to study certain publications recently received. These give an excellent idea of the thorough manner in which standardization is practiced in the "Wernerwerk," an immense factory employing 18,000 men and producing electrical machinery. It is owned by Siemens & Halske and is located at Siemensstadt near Berlin. These papers also illustrate the very close coöperation existing between German industry and the Normenausschuss der Deutschen Industrie (D I N). Siemens & Halske, who started standardization with the very foundation of their firm, now use some 500 standards sheets, and accept without alteration, or with slight changes to suit plant requirements, the standards sheets of the D I N, the Society of German Electrotechnical Industry, and other similar bodies.

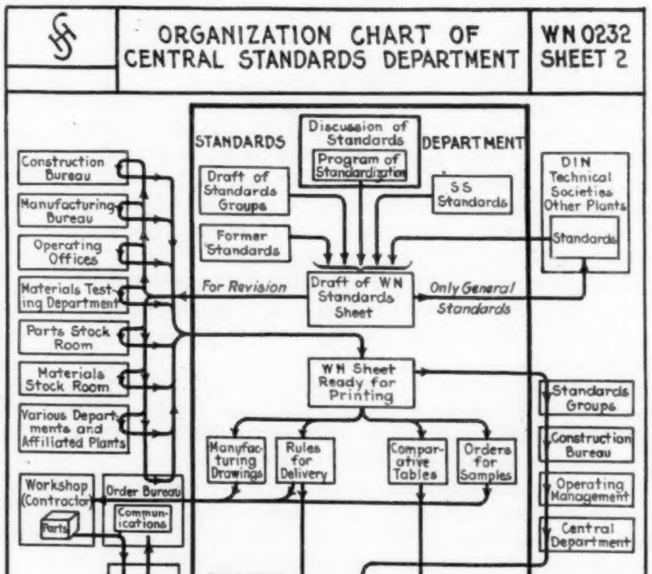


FIG. 1 ORGANIZATION CHART OF CENTRAL STANDARDS DEPARTMENT

The charts shown as Figs. 1 and 2 indicate the extremely careful way in which the application of standards has been organized in this plant. The Standards Department has definite relationships with every department and bureau of the entire plant, with the D I N, and with the technical societies. Apparently a complete system exists for the receipt and acceptance of D I N Standards, for their modification and revision when necessary, for their printing in Siemens & Halske form, for their incorporation in the general work of the factory, for their definite filing in folders, ledgers, and standard books, and for their distribution to various departments and bureaus of the factory.

The charts also indicate that a system is just as carefully worked out for the preparation of standards by the Standards Department

[1] The material upon which the following article is based was supplied through the courtesy of Dr. G. Leifer, chief engineer of the Werner plant of the Siemens & Halske Works, Berlin. The data were prepared by Dr. Leifer and Dr. Goller of the Siemens & Halske works.

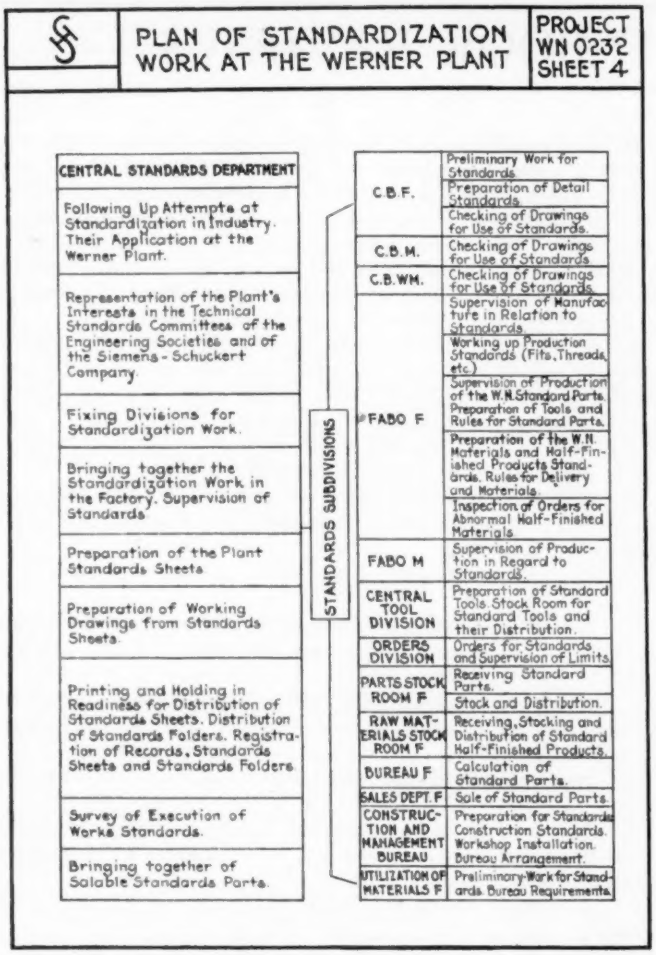


FIG. 2 PLAN OF STANDARDIZATION WORK AT THE WERNER PLANT

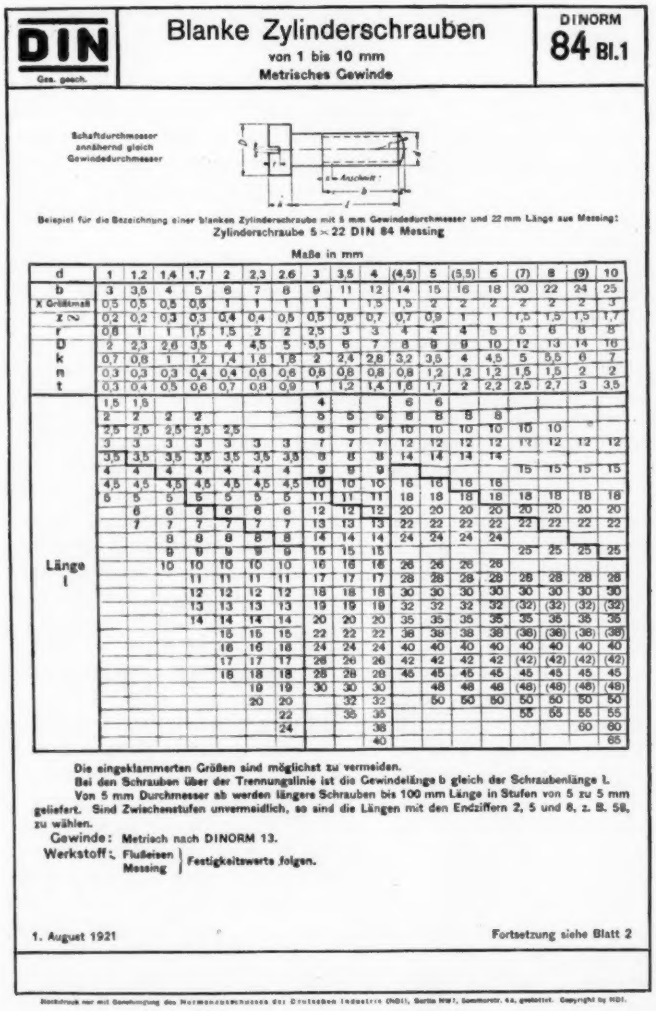
of the factory itself. Provision is made for the initiation and criticism of proposals by other departments, and for the coöperation of all departments in the general work of standardization.

Table 1 consists of an index list of standards sheets and shows the thorough manner in which the standardization work is made to cover systematically every possible activity of the plant. Everything that is capable of standardization is provided for in this "Index for Groups and Classes." Group 0, for instance contains the rules for the drawing up of standards sheets and the rules for drafting and distribution. Group 1 includes certain standard manufacturing rules. Here we find reference to manufacturing tolerances. Group 2 covers instructions for calculations; for instance, the calculation of leaf and helical springs. Group 3 contains the standards which form a basis for other standards, such as preferred numbers, units of measure, etc. Group 4 pertains to the properties of materials and provides for the correct utilization of these materials in construction and manufacture. Group 5 gives a review of the dimensions in which half-finished materials are kept in the stock room. Group 6 comprises mostly screws, nuts, etc., which are employed in Siemens & Halske factories. Group 7 includes standards for electrical parts of the machines which they manufacture. The standards are continually extended and developed in accordance with current requirements, but always fall within the scope of this classification.

Great care is shown in the preparation of standards sheets. Definite rules have been drawn up to cover the manner in which D I N sheets are prepared for international circularization, the marking and indexing of the sheets, and the preparation of drawings both for showing standard dimensions and for actual factory production work.

The system of numbering calls for three or four places of figures as required. The Werner factory standards book comprises ten chief groups, from 0 to 9. This group subdivision fixes the figure in the first place from the left. Each main group is subdivided into ten classes also numbered from 0 to 9. These classes are indicated by the second place of figures. The third and fourth places fix the number of the sheet itself. A typical standards sheet of the D I N is reproduced as Fig. 3.

Whether or not this comprehensive and minute system will appeal to American manufacturers is not certain, but it is without question interesting material for study by our production engineers.



DIN Ges. gesch. | Blanke Zylinderschrauben von 1 bis 10 mm Metrisches Gewinde | DINORM 84 Bl.1

Beispiel für die Bezeichnung einer blanken Zylinderschraube mit 5 mm Gewindedurchmesser und 22 mm Länge aus Messing:
Zylinderschraube 5 × 22 DIN 84 Messing

Maße in mm

d	1	1,2	1,4	1,7	2	2,3	2,6	3	3,5	4	(4,5)	5	(5,5)	6	(7)	8	(9)	10
b	3	3,5	4	5	6	7	8	9	11	12	14	15	16	18	20	22	24	25
x Größtmaß	0,5	0,5	0,5	0,5	1	1	1	1	1	1,5	1,5	2	2	2	2	2	2	3
z ~	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,9	1	1	1,5	1,5	1,5	1,7
r	0,8	1	1	1,5	1,5	2	2	2,5	3	3	4	4	4	5	5	6	8	8
D	2	2,3	2,6	3,5	4	4,5	5	5,5	6	7	8	9	9	10	12	13	14	16
k	0,7	0,8	1	1,2	1,4	1,6	1,8	2	2,4	2,8	3,2	3,5	4	4,5	5	5,5	6	7
n	0,3	0,3	0,3	0,4	0,4	0,6	0,6	0,6	0,8	0,8	0,8	1,2	1,2	1,2	1,5	1,5	2	2
t	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,2	1,4	1,6	1,7	2	2,2	2,5	2,7	3	3,5
Länge l	1,5	1,5						4			6	6						
	2	2	2	2				5	5	5	8	8	8	8				
	2,5	2,5	2,5	2,5	2,5			6	6	6	10	10	10	10	10	10		
	3	3	3	3	3	3	3	7	7	7	12	12	12	12	12	12	12	12
	3,5	3,5	3,5	3,5	3,5	3,5	3,5	8	8	8	14	14	14	14				
	4	4	4	4	4	4	4	9	9	9					15	15	15	15
	4,5	4,5	4,5	4,5	4,5	4,5	4,5	10	10	10	16	16	16	16				
	5	5	5	5	5	5	5	11	11	11	18	18	18	18	18	18	18	18
		6	6	6	6	6	6	12	12	12	20	20	20	20	20	20	20	20
		7	7	7	7	7	7	13	13	13	22	22	22	22	22	22	22	22
			8	8	8	8	8	14	14	14	24	24	24	24				
			9	9	9	9	9	15	15	15					25	25	25	25
			10	10	10	10	10	16	16	16	26	26	26	26				
				11	11	11	11	17	17	17	28	28	28	28	28	28	28	28
				12	12	12	12	18	18	18	30	30	30	30	30	30	30	30
				13	13	13	13	19	19	19	32	32	32	32	(32)	(32)	(32)	(32)
				14	14	14	14	20	20	20	35	35	35	35	35	35	35	35
					15	15	15	22	22	22	38	38	38	38	(38)	(38)	(38)	(38)
					16	16	16	24	24	24	40	40	40	40	40	40	40	40
					17	17	17	26	26	26	42	42	42	42	(42)	(42)	(42)	(42)
					18	18	18	28	28	28	45	45	45	45	45	45	45	45
						19	19	30	30	30		48	48	48	(48)	(48)	(48)	(48)
						20	20		32	32		50	50	50	50	50	50	50
							22		35	35					55	55	55	55
							24			38							60	60
										40								65

Die eingeklammerten Größen sind möglichst zu vermeiden.
Bei den Schrauben über der Trennungslinie ist die Gewindelänge b gleich der Schraubenlänge l.
Von 5 mm Durchmesser ab werden längere Schrauben bis 100 mm Länge in Stufen von 5 zu 5 mm geliefert. Sind Zwischenstufen unvermeidlich, so sind die Längen mit den Endziffern 2, 5 und 8, z. B. 58, zu wählen.
Gewinde: Metrisch nach DINORM 13.
Werkstoff: Flußeisen / Messing } Festigkeitswerte folgen.

1. August 1921 — Fortsetzung siehe Blatt 2

FIG. 3 A TYPICAL D I N STANDARDS SHEET

TRANSLATION:
Title: Cylindrical Screw Blanks from 1 to 10 mm. Diameter—Metric Thread.
To the left of figure: Shank diameter approximately equal to thread diameter.
In the figure: *Anschnitt* = cut.
Under the figure: Method of specifying a brass cylindrical screw blank of, say, 5 mm. thread diameter and 22 mm. long: Cylindrical Screw 5 x 22 D I N 84 Brass.
Above table: *Masse in mm.* = Dimensions in millimeters.
First column of table: *Grösstmass* = Largest dimension.
Under the table:
The dimensions in parentheses ( ) are, if possible, to be avoided.
For the screws just above the heavy stepped division line the thread length *b* is equal to the screw length *l*.
Above 5 mm. diameter, longer screws up to 100 mm. in length will be furnished in steps of 5 mm. If intermediate lengths are unavoidable, then those ending with the digits 2, 5 and 8 are to be chosen; e.g., 58.
Thread: Metric in accordance with DINORM 13.
Material: Steel / Brass } Strength as follows:

(For continuation see Sheet 2)

Index to Volume 45 of "Mechanical Engineering"

AN Index to Volume 45 of MECHANICAL ENGINEERING is now in the course of preparation, and, it is expected, will be issued early in February. A copy of this Index will be sent to each member of the Society or subscriber who sends in a written request therefor. Those who wish to receive an Index to MECHANICAL ENGINEERING regularly each year may have their names entered upon a permanent list for that purpose upon application. In order that no more copies may be printed than are necessary to supply the demand, requests for copies should be received at headquarters not later than February 1.

LIBRARY NOTES AND BOOK REVIEWS

A Survey of Industry

Commerce Year Book. 1922. Bureau of Foreign and Domestic Commerce, Department of Agriculture, Washington, D. C., 1923. Cloth board, 6 × 9 in., 690 pp., $0.60.

The Bureau of Foreign and Domestic Commerce of the Department of Commerce has just issued its first Commerce Year Book, covering the year 1922 and the early part of 1923. This volume is one of a series of publications which have been published by the different bureaus of the Department of Commerce since this department of the Government was placed in charge of Secretary Hoover.

The book, in common with similar publications such as Commerce Reports, Survey of Current Business, and certain of the Government documents on the Census of Manufactures, is an attempt to give a concise picture of what is going on in industry by bringing together masses of statistics in codified and analyzed form, so that they can be easily reviewed by those men in industry who are seeking the facts with regard to the business of the nation.

The Commerce Year Book puts into compact form a tremendous mass of statistical information gathered not only through the Bureau of Foreign and Domestic Commerce, but through the Bureau of Census, the Bureau of Standards, all bureaus of the Department of Commerce, and Government departments outside of the Department of Commerce, including certain statistics from the Department of Agriculture. The book also quotes liberally from private statistical sources, so that it may be said to represent a survey of industry organized on the basis of both public and private sources and coördinated by the Bureau of Foreign and Domestic Commerce.

In reviewing the detail of this first year book of the Department of Commerce, outside of the fact that the statistics show in general an expanding business in 1922–1923, probably the publication will be found to be most valuable in laying out long-range programs for industry. To most users of the volume the statistics outside of their own industry will probably be most interesting, and as a reference work for those who would make a study of the industries to which theirs is related the book has its greatest value. The detailed statistics of specific industries are found in other department publications and other sources, so that the book is not an exhaustive study of any single industry, but rather attempts to give a composite picture of related industries. The Year Book shows in detail that practically every manufacturing and mining industry showed some increase of production in 1922 and in the first part of 1923, but that marked variations appear in the rate of growth.

From the point of view of an engineer the Year Book will be found most useful as a reference volume of general statistics which reflect the condition of industry from a business angle. The book is for sale by the Superintendent of Documents, Washington, D. C., and the price is merely a nominal one.

F. M. Feiker.[1]

The New Lending Service of the Library

The Library Board has long wished to establish a lending department in the Engineering Societies Library, but has found it impossible to do so, as its resources were not large enough to permit the necessary duplication of books. Recently, however, a plan has been proposed for lending books on a rental basis. This plan, having been endorsed by the four national engineering societies and the United Engineering Society, has been adopted.

The Library now has available for lending a good collection of modern, up-to-date American books on engineering. Additions will be made as demands indicate and it is hoped that it will be possible to fill any reasonable requests. These books will be sent, by mail or express, to members in North America. It is hoped that members of the four national engineering societies who seldom can visit the Library will find this service convenient, and that they will make full use of it. If members avail themselves freely of the service, it is expected that the receipts from loans will justify the continuance of the plan. Members can also assist materially by returning books and paying bills promptly, and by making requests as definite as possible, so that correspondence may be reduced to a minimum and the overhead expense kept low.

As the collection will be constantly changing, through the withdrawal of unused books and the addition of new ones, it will not be possible to print a catalog. Most of the recent books published in this country are available.* If a member does not have a particular book in mind, but wishes one on some subject, the Director will be glad to send the best book available.

The rules that follow have been adopted tentatively. Members are invited to suggest changes that would give them service better adapted to their needs.

Rules

1 Books will be lent to members of the four national engineering societies and of other societies that contribute regularly to the support of the Library.

2 A rental of five cents a day will be charged for each volume. An allowance will be made for time of transit, based on the average time of mail from New York.

3 Transportation charges and insurance will be charged to the borrower.

4 The Library will be responsible for losses during shipment to the borrower. The borrower will be responsible for the return of books to the Library.

5 All damage, except reasonable wear, will be charged to the borrower.

6 Members may purchase, at publishers' prices, any books that they borrow. If the Library is notified within ten days after receipt of the book of the intention to purchase, no rental or transportation will be charged.

In asking for loans members will please indicate clearly the books wanted. They should also state the society to which they belong, and the address to which the books are to be sent.

Correspondence should be addressed to the Engineering Societies Library, 29 West Thirty-Ninth Street, New York, N. Y.

At present the Library cannot lend books in foreign languages. Periodicals and the transactions of societies are also not available. Photoprint copies of these will be supplied at cost, as in the past.

American Lumber Industry. By Nelson Courtlandt Brown. John Wiley & Sons, New York, Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 279 pp., illus., maps, tables, $3.

Professor Brown's book is intended as a brief yet comprehensive account of the lumber industry as a whole. He discusses the forests, logging methods, the manufacture, seasoning and grading of lumber, commercial sizes, selling and distributing, shipping, consumption, preservation, export and import, trade associations and lumber substitutes. The book is intended as a textbook for forest schools and as a reference book for those in the industry.

A. S. T. M. Tentative Standards, 1923. By the American Society for Testing Materials. The Society, Philadelphia, 1923. Cloth, 6 × 9 in., 859 pp., illus., diagrams, tables, $8.

The 1923 issue of this annual contains 190 tentative standard specifications and methods. These methods are published for the purpose of eliciting criticism before they are presented for adoption as standards by the society. The specifications included relate to ferrous and non-ferrous metals; cement, lime, and clay products; preservative coatings; petroleum products; lubricants; road materials; coal; coke; timber; waterproofing; insulants; shipping containers; rubber products; textiles; thermometers. Tentative revisions of 42 present standards are also given.

[1] Operating vice-president, Society for Electric Development, New York. Assoc. A.S.M.E.

HYDRO-ELECTRIC POWER STATIONS. By David B. Rushmore and Eric A. Lof. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 830 pp., illus., diagrams, tables, $7.50.

This book treats of the problems which must be solved in connection with the construction and management of a hydroelectric power station, so that the manager or engineer may select power equipment and fully understand the economic factors that enter into each solution. The subject is approached from the point of view of the practical engineer; both hydraulic and electrical questions are considered, including all matters essential to design and operation. The new edition has been practically rewritten to meet the recent important changes in practice.

DIESEL ENGINES. By Lacey H. Morrison. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 598 pp., illus., diagrams, $5.

This volume treats of the history and theory of this engine, describes the American commercial types, with details of their main parts, and gives much information on erection, adjustment, and operation. The economic status of the engine is discussed and there are chapters on fuel, lubrication, testing, etc. One chapter treats of airless injection oil engines.

Report on Art of Cutting Metals

(Continued from page 30)

object under stress is projected on to a screen, and if a white light is used brilliant colors of rainbow pattern appear and indicate in a particular manner, the stress in the material which the light has passed through. It is owing to this effect that an optical analysis of stress distribution in a transparent body is possible.

155 The observations made as the result of trials brought out the fact that the stress distribution remains invariable over a limited range of speed, therefore the total work done is a linear function of the speed. Putting this in another way, it may be said that the work required to remove a given weight of nitrocellulose is a constant within the limits of the experiments for a cut of definite thickness.

156 In the discussion following the reading of this paper it was shown that the statement "that the work required to remove a given weight of nitrocellulose is a constant within the limits of these experiments," is also true of steel. Experiments made in 1908 by Mr. P. V. Vernon showed that the amount of work required to remove a given weight of steel was practically independent of the speed. Taking for example, a 2-in. bar which had been reduced to $1^3/_4$ in. at different speeds, varying from 107 ft. per min. to 210 ft. per min., the metal removed per horsepower per minute varied from 0.33 to 0.34 cu. in., so that the amount of metal removed per hp. per min. was practically constant over that variation of cutting speed. In connection with screw cutting a similar set of experiments were made, in which the ratio of hp. to r.p.m. was practically identical all the way through, which meant that the pressure on the dies was the same, no matter at what speed the work was done.

157 On the whole the tests may be regarded as an experimental confirmation of the theory of stress distribution at the apex of a wedge, and if this may be taken for granted it introduces a considerable simplification in further work on the action of cutting tools by this method since the stress distribution on this assumption can be inferred from the color bands alone, without the necessity of lateral measurements, and only one point on the color band needs calibrating in order to obtain the stress at any point of it within the elastic region of the tool. It appears possible that the distribution nearly up to the point of the cutting edge can also be determined in this manner, and the sum of all the forces acting on the tool expressed approximately as a single force acting at this edge.

PERSONNEL OF SPECIAL RESEARCH COMMITTEE ON CUTTING AND FORMING OF METALS

B. H. BLOOD, *Chairman*, General Manager of Pratt & Whitney Company, Hartford, Conn.

C. A. BECKETT, *Secretary*, Associate, School of Engineering, Columbia University, New York, N. Y.

A. E. BELLIS, *President*, The Bellis Heat Treating Company, New Haven, Conn.

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W. TRINKS, Professor, Department of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

November 9, 1923.

Discussion

THE preceding Research Report was presented at the Machine-Shop Practice Session on Thursday morning, December 6, by B. H. Blood, Chairman of the Committee under whose auspices it was prepared.

In his presentation Mr. Blood stated that one of the principal functions of the Committee would be to encourage the publication of research results for the good of the industries of the country. Mr. Blood showed how the interchange of technical information in industry during the past generation had amplified the development of American manufacture. The Committee is planning to coöperate with metallurgical and steel-treating societies, as the work being done by them is of great importance in metal-working research. He stressed the importance of definitions for the various qualities and properties of metals.

F. E. Cardullo[1] told of thesis work at the University of Cincinnati where they are investigating temperatures at the cutting edges of cutting tools, the various qualities of cutting lubricants, and are seeking to establish a numerical standard for comparing finishes of machined surfaces. Mr. Cardullo suggested that hardness be defined as a property of material as expressed by the product of the elastic limit and the modulus of elasticity.

O. W. Boston[2] stated that he was working on a design of a dynamometer which will make it possible to measure the force acting on the cutting tool.

A. E. Bellis[3] discussed the subject from the point of view of the heat treater and told of perfecting heating media which increased the performance of tools materially. He expressed the hope that it would be possible to develop an authentic performance test by which the effectiveness of heat-treatment processes could be measured.

A. L. DeLeeuw[4] emphasized the importance of considering the power consumption of various cutting tools as an important element in determining the most effective design of the tool. He stressed the fact that the investigation of the curve of relation between tool angles and power consumption is one of the most important things the Committee can undertake, as it would show the direction for improvement either in the nature of the steel or in the nature of the shape and angles of the tools we are using.

R. E. Flanders[5] pointed out that in many production machines tools are being used with sharper angles than is possible in an engine lathe with resulting smaller power consumption, less strain and greater production. Mr. Flanders also emphasized the need for defining the quality known as machinability.

Harry Cadwalader[6] asked for information about cutting and forming aluminum.

E. F. DuBrul[7] told of the need for coördinated research in the metal-working industries which has been backward in the use of research compared to many other industries.

R. Poliakoff[8] submitted a detailed discussion of the technical phases of the report and contributed many results of tests on materials of cutting tools and lathe breakdown tests.

[1] Chief Engr., The G. A. Gray Co., Cincinnati, O. Mem. A.S.M.E.
[2] Asst. Prof., Machine Shop Practice, University of Michigan. Mem. A.S.M.E.
[3] Pres., Bellis Heat Treating Co., New Haven, Conn.
[4] Consulting Engr., New York. Mem. A.S.M.E.
[5] Jones & Lamson Machine Co., Springfield, Vt. Mem. A.S.M.E.
[6] Genl. Mgr., National Machine Tool Builders' Assn., Cincinnati, Ohio. Mem. A.S.M.E.
[7] Efficiency Engr., President, Standard Shop Equipment Co., Philadelphia, Pa. Mem. A.S.M.E.
[8] New York, N. Y. Mem. A.S.M.E.

THE ENGINEERING INDEX

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Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 145-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AUGER BITS

Manufacturing. Manufacturing Auger and Machine Bits, Charles O. Herb. Machy. (N. Y.), vol. 30, no. 4, Dec. 1923, pp. 271–276, 18 figs. Describes operations in producing these tools, according to practice of Greenlee Bros. & Co., Rockford, Ill.

AUTOMOBILES

Braking. French Device Automatically Takes Up Slack in Braking Systems. Automotive Industries, vol. 49, no. 22, Nov. 29, 1923, pp. 1104–1105, 2 figs. Maintains constant clearance between brake sectors and drum; arrangement worked out to obviate difficulty arising when brake-shaft lever comes nearly into line with rod.

BEARINGS, BALL

Ball Manufacture. Making and Testing Steel Balls, K. H. Lansing. Iron Trade Rev., vol. 73, no. 23, Dec. 6, 1923, pp. 1549–1552, 9 figs. Cold pressing, hot pressing or forging may constitute first step; balls are rough-ground before hardening and finish-ground after hardening; product carefully inspected following each operation.

BENDING MACHINES

Tube. A New Tube Bending Machine. Engineer, vol. 136, no. 3541, Nov. 9, 1923, p. 514, 3 figs. New type of machine with which steel, iron and other metal tubes can be bent cold without filling and without formers, only tools required being slipper and set of grips and mandrel heads for each bore of tube.

BOILER FEEDWATER

Dissolved Oxygen in. Field Method For Determining Dissolved Oxygen, G. A. DeGraaf. Power, vol. 58, no. 24, Dec. 11, 1923, pp. 930–933, 8 figs. Describes improved and simplified method and gives results obtained in tests at large power station.

BOILER PLANTS

Oil-Burning. R. H. Macy Power Plant Changes from Coal to Oil Burning. Power, vol. 58, no. 23, Dec. 4, 1923, pp. 910–912, 4 figs. Six of eleven coal-fired boilers change over to oil burning, which will result in ultimate saving of $50,000 a year and provide additional capacity required for new store.

BOILERS

Mercury-Vapor. The Emmet Mercury Boiler. Power, vol. 58, no. 23, Dec. 4, 1923, pp. 876–880, 7 figs. Notes on its development; problems encountered and description of Hartford (Conn.) installation; first of its kind to be placed on commercial load.

COAL STORAGE

Fire-Protection System. Fedco Protectometer System for Stored Coal. Power, vol. 58, no. 22, Nov. 27, 1923, p. 850, 3 figs. System developed as means of detecting any case of heat development in sufficient time to permit removal of hot coal before serious loss of heat value has been incurred or before actual fire breaks out.

COST ACCOUNTING

Factory. Classification of Industrial Expense Items Including Their Application, H. W. Maynard. Management & Administration, vol. 6, no. 6, Dec. 1923, pp. 751–753, 1 fig. Summary of management data; distribution of estimated fixed charges; classification of miscellaneous expenses; selling and administrative expenses.

CUPOLAS

Schuermann. Side-Blast Cupola in Operation at Chicago, S. G. Werner. Iron Age, vol. 112, no. 21, Nov. 22, 1923, pp. 1377–1379, 3 figs. Describes Schuermann system, installed for first time in America; other developments in German foundry practice discussed by head of German foundry association. (Abstract.) Paper read before Chicago Foundrymen's Club.

DIES

Drawing, Design. The Action of Drawing Dies on Metals, D. L. Mathias. Forging—Stamping—Heat Treating, vol. 9, no. 11, Nov. 1923, pp. 484–486, 2 figs. Importance of design; action of dies on metal; analyzing stresses; necessity of annealing; inspecting materials.

DIESEL ENGINES

Central Stations. Diesel Engine Shows Low Fuel Consumption, Ray C. Burrus. Power Plant Eng., vol. 27, no. 23, Dec. 1, 1923, pp. 1183–1184, 2 figs. Little variation in consumption between half and full load shown in acceptance test at South Bend, N. J., plant.

Possibilities of Diesel Engines for Central-Station Service, E. B. Pollister. Elec. World, vol. 82, no. 22, Dec. 1, 1923, pp. 1111–1115, 6 figs. Points out that equipment can be built in large sizes despite assumption to contrary; erroneous conception prevails as to its cost and limitations; analyses of cost of 5000-kw. and 20,000-kw. stations.

Manufacture. Building Vertical Oil Engines, Fred R. Daniels. Machy. (N. Y), vol. 30, no. 4, Dec. 1923, pp. 247–252, 13 figs. Describes practice at the De La Vergne Machine Co., New York City.

ELECTRIC FURNACES

Heat-Treating. Electric Heat Treating Furnaces, E. F. Collins. Forging—Stamping—Heat Treating, vol. 9, no. 11, Nov. 1923, pp. 482–483, 4 figs. Features of unmuffled metallic resister furnace are good heat distribution, and sensitive temperature control.

Melting, Multiple Electric. Multiple Electric Melting, Enrique Touceda. Iron Age, vol. 112, no. 22, Nov. 29, 1923, pp. 1441–1442, 3 figs. Describes new method of handling electric furnaces; makes use of two furnaces on turntable with one transformer and set of electrodes. (Abstract.) Paper before Nat. Founders' Assn.

EMPLOYMENT MANAGEMENT

Long Service, Recognition of. Recognition of Long-Time Service, L. D. Burlingame. Management & Administration, vol. 6, no. 6, Dec. 1923, pp. 767–769, 6 figs. Method used by Brown & Sharpe Mfg. Co. to maintain stable working force.

FANS

Balancing High-Speed. Balancing High-Speed Fans, A. L. Greene. Iron Age, vol. 112, no. 23, Dec. 6, 1923, pp. 1512–1513, 2 figs. Importance of correct dynamic balance stressed; static balance is not enough.

FIRE PROTECTION

Iron and Steel Plants. Protecting Iron and Steel Plants from Fire, Jas. M. Woltz. Iron Trade Rev., vol. 73, no. 22, Nov. 29, 1923, 1477–1479, 4 figs. Well-organized companies of trained employees and complete equipment necessary; how one large valley interest solved problem. (Abstract.) Paper read before Nat. Safety Council.

FLOW OF LIQUIDS

Flow Meter. A Small Flow Meter. Engineer, vol. 136, no. 3542, Nov. 16, 1923, p. 540, 3 figs. Measures very small flows of liquids, such as supply of lubricating oil to bearings, or gasoline consumed by automobile engine.

FLUE-GAS ANALYSIS

CO_2 Meter. Brown Electrical CO_2 Meter. Power, vol. 58, no. 22, Nov. 27, 1923, pp. 383–384, 2 figs. Indicating and recording meter developed by Brown Instrument Co., Philadelphia, utilizing method of gas analysis based on difference in thermal conductivity of various gases.

FREIGHT HANDLING

Automobiles, Loading in Cars. Saving Millions by Better Loading, Edward S. Evans. Management & Administration, vol. 6, no. 6, Dec. 1923, pp. 715–718, 9 figs. Points out that application of scientific methods to loading of automobiles in freight cars has saved industry $50,000,000 in past 8 years; details of improved methods of loading and shipping; loading during war.

GEARS

Nomenclature. Proposed Standard Nomenclature for Gearing. Am. Mach., vol. 59, no. 22, Nov. 29, 1923, pp. 801–802. Terms proposed by sectional committee of Gear Mfrs. Assn. on standardization of gears; offered for study and criticism at large. See also Automotive Industries, vol. 49, no. 22, Nov. 29, 1923, p. 1111.

Worm. Recommended Practice for the Design of Worm Gearing. Am. Mach., vol. 59, no. 23, Dec. 6, 1923, pp. 845–846, 3 figs. Reduction of number of worm gear hobs carried in stock; provision made for using hobs already in existence; recommendations for new design. Report of Work Gear Committee of Am. Gear Mfrs. Assn.

GRINDING MACHINES

Chilled Rolls. Rapid Roll-Grinding Machine. Engineering, vol. 106, no. 3020, Nov. 16, 1923, p. 633, 3 figs. Outstanding feature is use of complete bridge instead of side bracket to support grinding wheel; it is said to permit such greatly increased cuts to be taken that grinding of certain classes of chilled rolls can be carried out in one-sixth of time required with machines of ordinary type.

HYDROELECTRIC DEVELOPMENTS

Hudson River, N. Y. Sherman Island Hydro-Electric Development of the International Paper Company. Power, vol. 58, no. 22, Nov. 27, 1923, pp. 836–842, 14 figs. 50,000-hp. development on Hudson River, consisting of five 10,000-hp. vertical Francis turbines to operate under 66-ft. head; power house and canal are constructed on sand underlain in many places with quicksand; dam rests on glacial deposits and is of special construction and canal, over 3500 ft. long, is concrete-lined.

INDUSTRIAL MANAGEMENT

Cost Control by Budget. Control Through Organization and Budgets, Thos. B. Fordhan and Edw. H. Tingley. Management & Administration, vol. 6, no. 6, Dec. 1923, pp. 719–724. Responsibilities and relations of four operating divisions: manufacturing, finance, engineering, sales.

Overhead Costs. Establishing Overhead Standards, R. W. Darnell. Management & Administration, vol. 6, no. 6, Dec. 1923, pp. 755–762, 3 figs. Explains accounting treatment of overhead both in factory and in office; distribution of overhead and establishment of standard overhead rates; adjustment of discrepancies; make-up of budget and bonus plan for keeping over-head done in factory; control of overhead element of cost.

LOCOMOTIVES

American, Life of. The Useful Life of American Locomotives, Lawford H. Fry. Engineering, vol. 106, no. 3020, Nov. 16, 1923, pp. 609–611, 4 figs. partly on p. 624. Facts as to life and service of locomotives in United States.

LUBRICATION

Bearings. Ball-Bearing Lubrication, A. Duckham and S. E. Bowrey. Engineering, vol. 106, no. 3020, Nov. 16, 1923, pp. 612–613, 1 fig. Factors governing selection of lubricant for ball bearings; semi-solid lubricants.

MACHINE TOOLS

Feet and Bases. Design of Machine Tool Feet and Bases, Fred Horner. Machy. (N. Y.), vol. 30, no. 4, Dec. 1923, pp. 259–262, 5 figs. Typical designs for different classes of machines.

MOLDING

Cover Core System. Simplifies Molding Practice, J. H. Eastham. Foundry, vol. 51, no. 22, Nov. 15, 1923, pp. 923–924, 5 figs. Combination of dry sand core and improved clamping arrangement reduced losses to gratifying extent when introduced in connection with manufacture of automobile flywheels.

MONEL METAL

Machining. Machining Monel Metal and Nickel, Machy. (N. Y.), vol. 30, no. 4, Dec. 1923, pp. 287–288, 1 fig. Information based on data obtained from Int. Nickel Co., New York City; instructions apply to machining of monel metal and malleable nickel.

MOTOR TRUCKS

International Harvester Co. New I. H. C. Truck Has Marked Changes in Engine and Steering Gear. Automotive Industries, vol. 49, no. 21, Nov. 22, 1923, pp. 1058–1060, 5 figs. Crankshaft is supported on two bearings; more rigid frame and heavier rear-axle shafts are used; internal expanding service brake replaces former contracting type; cooling by thermosiphon.

PRESSES

Inclinable. Design of Inclinable Power Presses, P. A. Friedell. Machy. (N. Y.), vol. 29, nos. 5 and 11, Jan. and July 1923, pp. 376–379 and 877–880 and vol. 30, no. 4, Dec. 1923, pp. 279–281, 2 figs. Jan.: Crankshaft, main bearings, slide or ram, and connection between crankshaft and slide. July: Proportioning frame, flywheel, and other parts. Dec.: Designing brake mechanism for power press, including estimating weight of reciprocating parts, determination of width and diameter of brake drum, and calculation of other brake parts.

POWER PLANTS

Power-Show Exhibits. Second Power Show a Big Success. Power, vol. 58, no. 24, Dec. 11, 1923, pp. 949–954, 9 figs. Review of exhibits, including pulverized-fuel, stokers, and forced-draft equipment; valves and fittings; boiler and turbine-room instrument; refractories.

ROLLING MILLS

Rolls, Alloy. Molybdenum in Cast Steel and Iron Rolls, W. Norman Bratton. Iron Age, vol. 112, no. 23, Dec. 6, 1923, pp. 1509–1510, 1 fig. Heat treatment and wearing qualities of low carbon; alloy iron rolls; general properties.

STEAM

High-Pressure. The Development and Future of High Pressures and Temperatures, H. B. Oatley, Power, vol. 58, no. 24, Dec. 11, 1923, pp. 966–967, 2 figs. Review of developments; factors that must be considered; water-level indicators and pipe connections; discusses advantages and disadvantages of increasing steam pressures and temperatures. (Abstract.) Paper presented before Providence Eng. Soc.

STEEL, HEAT TREATMENT OF

Electromagnetic. Electro-Magnetic Heat Treatment of Steel, L. W. Wild. Forging—Stamping—Heat Treating, vol. 9, no. 11, Nov. 1923, pp. 473–477, 8 figs. Produces perfectly hardened work, eliminating failures often resulting from faulty temperature indications.

WAGES

Standard Time System. Applies Standard Time System. Foundry, vol. 51, no. 23, Dec. 1, 1923, pp. 947–949. Describes plan of shop committees to consider problems of management affecting worker, advancement of workman's and company's interests, and standard time system established by Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

WELDS

Bronze-Steel. Bronze-Steel Welds, Geo. F. Comstock. Iron Age, vol. 112, no. 21, Nov. 22, 1923, pp. 1381–1382, 4 figs. Variations in microstructure with rods of different compositions; peculiar behavior of phosphorus.